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OU2 Closure Soft Studies Scientific Notebook

for

The Rocky Flats Environmental Technology Site

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ROCKY FLATS

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U.S. DEPARTMENT OF ENERGY
ROCKY FLATS ENVIRONMENTAL
RESTORATION MANAGEMENT

OU2 Closure Soil Studies Scientific
Notebook for The Rocky Flats
Environmental Technology Site



RFP/ERM-94-00021

**OU2 CLOSURE
SOIL STUDIES
SCIENTIFIC NOTEBOOK**

**U.S. DEPARTMENT OF ENERGY
The Rocky Flats Environmental Technology Site
Golden, Colorado**

ENVIRONMENTAL RESTORATION PROGRAM DIVISION

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OU2 Closure Soil Studies Scientific Notebook	Page:	i of iv

TABLE OF CONTENTS

Section	Page
1.0	BACKGROUND 1-1
2.0	PROJECT OBJECTIVES 2-1
3.0	PERSONNEL 3-1
3.1	Principle Investigator (PI) and Project Manager (PM) 3-1
3.2	Collaborating Principle Investigators (CO-PI) 3-1
4.0	PROCEDURES 4-1
4.1	Pit Location 4-1
4.1.1	Site Survey 4-1
4.1.2	Pit Location Procedures 4-1
4.1.3	Pit Excavation Procedures 4-1
4.1.4	Pit Characterization and Soil Sampling Procedures 4-3
4.1.5	Pit Backfilling and Site Restoration Procedure 4-3
4.2	Soil Water Samples 4-11
4.2.1	Principles of Zero Tension (ZT) Sampler Operation 4-11
4.2.2	ZT Sampler Installation 4-16
4.2.3	ZT Sampler Data 4-23
4.2.4	ZT Sampler Problems and Solutions 4-23
4.2.5	Principles of Tension Soil Solution Sampler (TSSS) Operation 4-24
4.2.6	TSSS Installation and Calibration 4-26
4.2.7	Clusters 4-28
4.2.8	TSSS Problems and Solutions 4-29
4.3	Soil Moisture 4-34
4.3.1	Principles of Time Domain Reflectometry (TDR) Operation 4-34
4.3.2	TDR Installation and Calibration 4-35
4.3.3	TDR Data 4-41
4.3.4	TDR Problems and Solutions 4-41
4.4	Matric Potential 4-42
4.4.1	Principles of Tensiometer Operation 4-42
4.4.2	Tensiometer Installation 4-44
4.4.3	Tensiometer Data 4-46
4.4.4	Tensiometer Problems and Solutions 4-52
4.5	Hydraulic Conductivity 4-52
4.5.1	Principles of Tension Infiltrometer Operation 4-52
4.5.2	Tension Infiltrometer Data 4-59
4.6	Water Table 4-59
4.6.1	Principles of Piezometer Operation 4-59

4.6.2	Piezometer Installation	4-60
4.6.3	Piezometer Data	4-61
4.6.4	Piezometer Problems and Solutions	4-61
4.7	Soil Temperature	4-61
4.7.1	Principles of Temperature Probe Operation	4-61
4.7.2	Soil Temperature Probe Installation and Calibration	4-62
4.7.3	Soil Temperature Probe Data	4-62
4.7.4	Soil Temperature Probe Problems and Solutions	4-62
4.8	Precipitation	4-64
4.8.1	Principles of Rain Gauge Operation	4-64
4.8.2	Rain Gauge Installation and Calibration	4-64
4.8.3	Rain Gauge Data	4-64
4.8.4	Rain Gauge Problems and Solutions	4-65
4.9	Rain Simulation	4-65
4.9.1	Rain Simulation Operations	4-65
4.9.1.1	Delivery System	4-65
4.9.1.2	Delivery System Set Up and Operation	4-65
4.9.1.3	Application System	4-71
4.9.1.4	Precipitation Monitoring Equipment	4-72
4.9.1.5	Performance Testing and Preparation for Field Experiments	4-72
4.9.1.6	Rain Simulations	4-73
4.9.1.7	Precipitation Calculations	4-73
4.9.1.8	Field Experiments	4-76
4.9.2	Rain Simulation Problems and Solutions	4-76
4.10	Snow Melt Monitoring Component	4-78
4.10.1	Snow Melt Modelling	4-78
4.10.2	Snow Melt Monitoring Component Installation	4-79
4.10.3	Snow Melt Data	4-80
4.10.4	Snow Melt Monitoring Component Problems and Solutions	4-81
4.11	TDR Component Datalogger and Communications	4-82
4.11.1	Principles of Campbell Scientific TDR Component Operation	4-82
4.11.2	Campbell Scientific TDR Component Installation and Calibration	4-83
4.11.3	Campbell Scientific TDR Component Problems and Solutions	4-85
4.11.4	Telemetry Installation	4-86
4.11.5	Telemetry Problems and Solutions	4-86
4.12	Data Storage	4-86
4.12.1	Location of Collected Data	4-86
5.0	REFERENCES	5-1

Figure

1.0-1	Study Area Location Map	1-2
4.1.2-1	OU2 SSSP Pit Location Map	4-2
4.1.4-1	Instrument Location Maps for Pits 1 – 5	4-5
4.1.4-2	Instrument Location Map: Pit 1 NW Face	4-6
4.1.4-3	Instrument Location Map: Pit 2 NW Face	4-7
4.1.4-4	Instrument Location Map: Pit 3 NW Face	4-8
4.1.4-5	Instrument Location Map: Pit 4 NW Face	4-9

4.1.4-6	Instrument Location Map: Pit 5 NW Face	4-10
4.2.1-1	Zero Tension Sampler	4-12
4.2.1-2	Load Cell Assembly	4-13
4.2.1-3	Load Cell Assembly and Enclosure	4-14
4.2.1-4	Load Cell Pumping Unit	4-15
4.2.4-1	Correlation for All Load Cells	4-24
4.2.5-1	Tension Sampler	4-25
4.2.6-1	Tension Sampler Pumping Assembly: Plan View	4-27
4.4.1-1	Pit Face Showing Location os Tensiometers	4-43
4.5.1-1	Tension Infiltrometer	4-57
4.9.1-1	Rain Simulator Frame	4-66
4.9.1-2	Rain Simulator Frame – Sideview	4-67
4.9.1-3	Rain Simulator Frame – Adjustable Leg Detail	4-68
4.9.1-4	Rain Simulator Frame – Spray System End View	4-69
4.9.1-5	Rain Simulation Application System – Spraying System	4-70
4.12.1-1	Schematic Diagram of SWMS	4-87

Table

4.1.4-1	Soil Depth Profile	4-4
4.2.2-1	Trench TR-1 Zero Tension Samplers	4-17
4.2.2-2	Trench TR-2 Zero Tension Samplers	4-18
4.2.2-3	Trench TR-3 Zero Tension Sampler	4-19
4.2.2-4	Trench TR-4 Zero Tension Sampler	4-20
4.2.2-5	Trench TR-5 Zero Tension Sampler	4-21
4.2.2-6	Experimental ZT Samplers	4-21
4.2.2-7	Load Cell Calibrations	4-22
4.2.8-1	Tension Sampler Vacuum Tests	4-31
4.3.1-1	Trench TR-1 Tension Samplers and TDR Probes	4-36
4.3.1-2	Trench TR-2 Tension Samplers and TDR Probes	4-37
4.3.1-3	Trench TR-3 Tension Samplers and TDR Probes	4-38
4.3.1-4	Trench TR-4 Tension Samplers and TDR Probes	4-39
4.3.1-5	Trench TR-5 Tension Samplers and TDR Probes	4-40
4.4.2-1	Trench TR-1 Tensiometers	4-47
4.4.2-2	Trench TR-2 Tensiometers	4-48
4.4.2-3	Trench TR-3 Tensiometers	4-49
4.4.2-4	Trench TR-4 Tensiometers	4-50
4.4.2-5	Trench TR-4 Tensiometers	4-51
4.5.1-1	Trench TR-1 Infiltrometer Test Locations	4-53
4.5.1-2	Trench TR-2 Infiltrometer Test Locations	4-54
4.5.1-3	Trench TR-3 Infiltrometer Test Locations	4-54
4.5.1-4	Trench TR-4 Infiltrometer Test Locations	4-55
4.5.1-5	Trench TR-5 Infiltrometer Test Locations	4-56
4.6.2-1	Piezometer Data	4-60
4.7.2-1	Temperature Probes	4-63
4.9.1.3-1	Nozzle Specifications	4-72
4.9.1.7-1	Coefficients Used in Eq(3)	4-74
4.9.1.7-2	Contains the values used to obtain 5, 10, 15, and 30 minute estimations from one hour values	4-75

Appendices

Appendix I	Acronym List	A-I
Appendix II	OU2 Pit Locations and Line Profiles	A-II
Appendix III	Rocky Flats Field Activities Report – Pit Sampling	A-III
Appendix IV	Pre-Installation Calibration of Load Cells	A-IV
Appendix V	Manufacturer's Information for Tension Soil Solution Sampler	A-V
Appendix VI	Pre-Installation Calibration of TDR Probes	A-VI
Appendix VII	Tensiometer SOP	A-VII
Appendix VIII	Tension Infiltrometer SOP	A-VIII
Appendix IX	Piezometer Information	A-IX
Appendix X	Rain Simulation Calculations	A-X
Appendix XI	SSG_SNBK Bernoulli Data Diskette Index	A-XI

ENVIRONMENTAL RESTORATION
PROGRAM DIVISION
OU2 Closure Soil Studies
Scientific Notebook

Document Number:
Section:
Page:
Effective Date:

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7/26/94

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1.0 BACKGROUND

Reports of plutonium (Pu) and americium (Am) movement in groundwater over distances beyond several meters are rare. Hakonson et al. (1981) reviewed the transport of Pu in terrestrial systems and asserted that vertical leaching of soluble Pu through the soil is an important phenomenon. Other findings support this claim. Onishi et al. (1981) concluded that adsorbed Pu can be readily moved through the aqueous environment in colloidal forms. Recently, Penrose et al. (1990) found that Pu and Am were transported in groundwater for at least 3390 meters downgradient from the point of discharge.

Pu and Am were tightly or irreversibly bound to colloidal material (25 to 450 nm). Krey et al. (1976) attributed the successful application of the diffusion term in their Soil-Pu transport model at several diverse sites at the Rocky Flats Environmental Technology Site (RFETS) to transportability of Pu in soil interstitial waters rather than to soil characteristics. Minimal research has been conducted on the fate and transport of actinides in soils at RFETS. Studies are necessary to determine the physical and chemical attributes that govern the flow of water and plasma in the soils at RFETS.

Furthermore, activity of actinides in soils are usually studied by extracting the soil matter. In general, these analyses fail to provide important information regarding the transport mechanisms of actinides within the soil column. *In situ* measures are necessary. Analysis of the frequency, duration, and intensity of summer precipitation and spring snowmelt events, including direct measurements of solute transport in soils, will provide essential information to assess the form and magnitude of actinide movement in soil. The area chosen for these *in situ* measurements is shown in Figure 1.0-1.

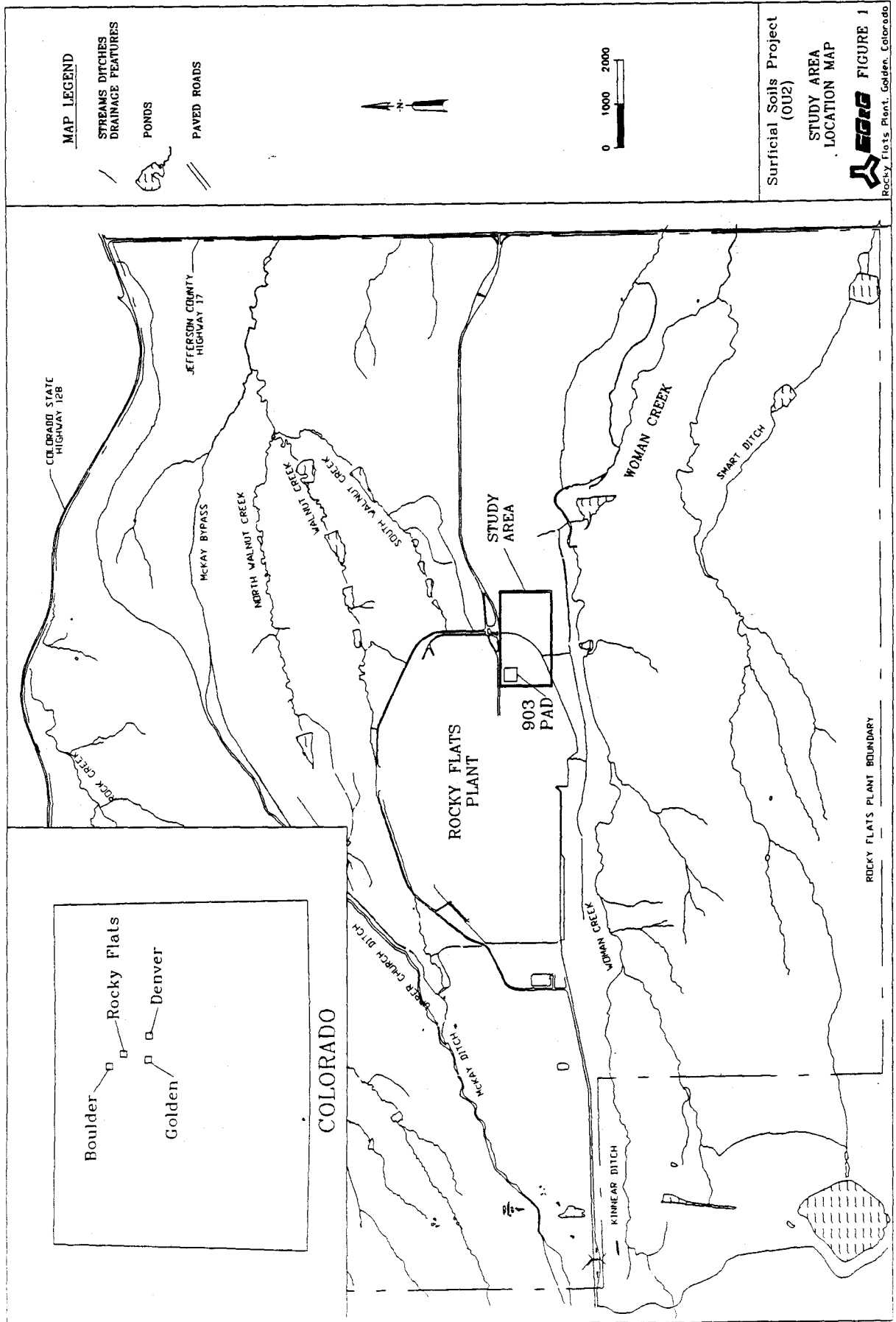


Figure 1.0-1 Study Area Location Map

2.0 PROJECT OBJECTIVES

The objectives of the project are to: (1) study and monitor the vertical flow in the soil environment upslope from Seep SW-53 during and after major precipitation events and snowmelt, and (2) assess the relationships between Soil-Pu in the interstitial water and Pu in Seep SW-53.

Geohydrological and geochemical data water will provide necessary constraints for the development of vadose zone modelings. The geochemical characterization study will include: (1) total concentrations of Pu and Am in soil interstitial waters that move freely (0-5 kPa) down the soil column, and (2) fractionation of actinides to colloidal and dissolved ($<0.1\mu\text{m}$) phases in freely flowing waters (0-5 kPa) and interstitial water at various matric potentials (5-10, 10-30, and 30-50 kPa).

3.0 PERSONNEL

3.1 PRINCIPLE INVESTIGATOR (PI) AND PROJECT MANAGER (PM)

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OU2 Closure

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4.0 PROCEDURES

4.1 PIT LOCATION

4.1.1 Site Survey

When pit excavations were concluded, an overall site survey listing pit locations and line profiles was conducted by Merrick and Co. The site survey is included in Appendix II.

4.1.2 Pit Location Procedures

The location of the five pits resulted from analysis of data collected from soil, groundwater, surface water, and geophysical investigations. During the summer of 1991 surficial soil sampling was conducted as part of the Surficial Soil Sampling Program (SSSP) for OU2.

The samples collected from surface water site Seep SW-53 had, occasionally, contained elevated concentrations of Pu. The area excavated for Pit 1 was chosen based on its proximity upgradient of Seep SW-53. Ground penetrating radar (GPR) and electromagnetic (EM) surveys were used to locate sites with possible subsurface lateral discontinuities. The location of Pits 2, 3, 4, and 5 (See Fig. 4.1.2-1) was determined from the results of the GPR survey. The survey results are summarized in a draft report titled "Geophysical Survey; Surficial Soil Sampling Program; 903 Pad, Mound, and East Pit Areas, Operable Unit No. 2," dated July 1992.

4.1.3 Pit Excavation Procedures

Before excavation, each pit location was oriented and staked by the project PI and pre-entry radiological and air quality surveys were conducted by Health and Safety (H&S) personnel. The pit area was sealed to prevent trampling of soil and vegetation. The pits were excavated according to Standard Operating Procedure (SOP) G.T.7, "Logging and Sampling of Test Pits, Trenches, and Construction Excavations," Section 5.2.1; "Excavation." The backhoe excavated the pits to approximately 1.2 m. Flooding occurred when groundwater was encountered 1.1 m deep at Pit 1. The pit was back-filled with clean gravel to a depth of 0.9 m.

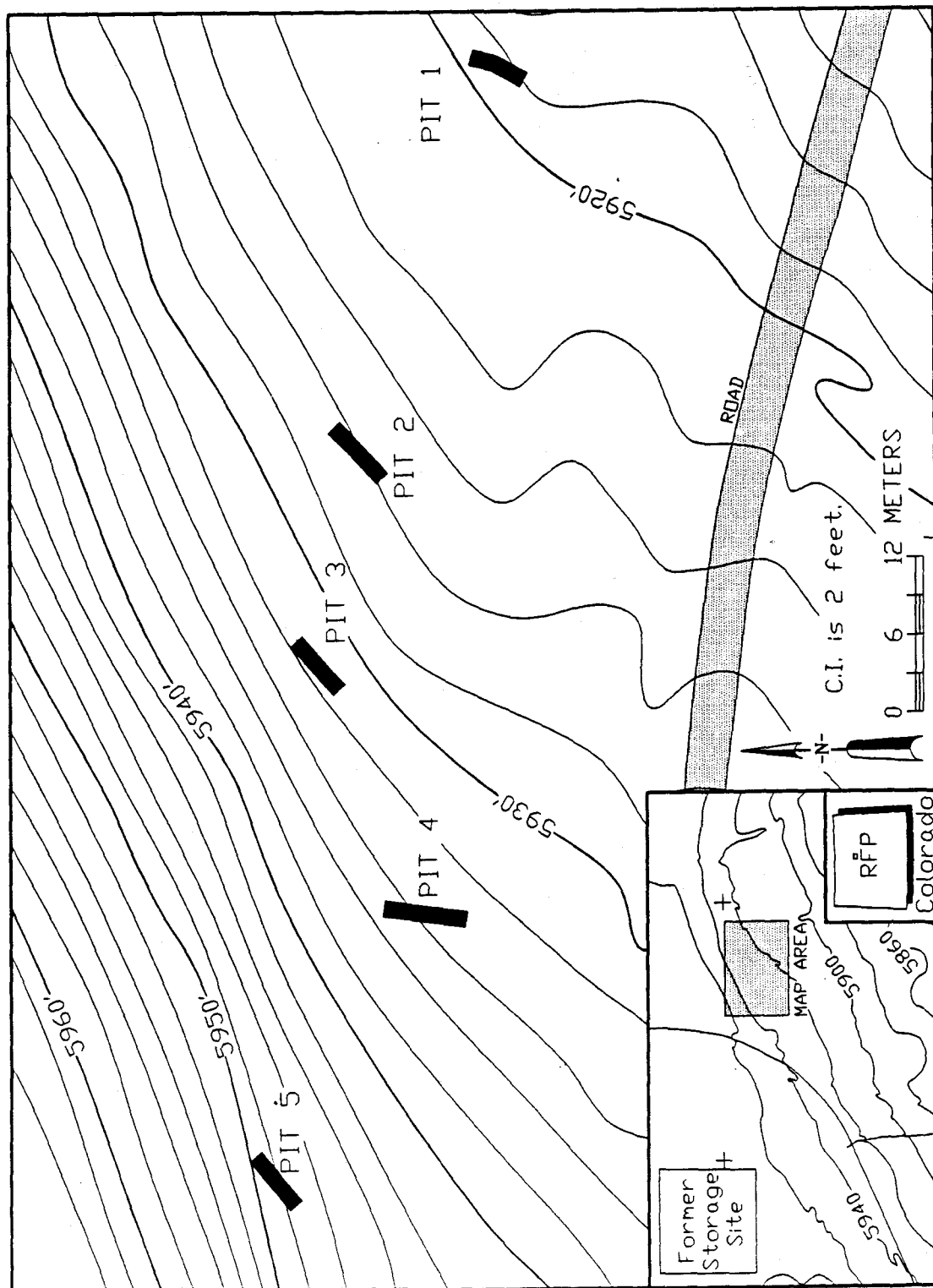


Figure 4.1.2-1 OU2 SSSP Pit Location Map

During pit excavation, soils were removed sequentially by diagnostic horizon and placed in separate piles. The soils from Pit 1 were placed upon plastic sheeting 10 m from the pit. Each diagnostic horizon was placed in its own pile and then covered with additional plastic sheeting. On subsequent pits, the spoils were placed by horizon into one of five 2.5 m long x 1.2 m wide x 1 m deep boxes. For convenience, boxes were located adjacent to the pit. The boxes were lined with plastic sheeting, filled with soil, covered with plastic, and then lids were placed upon the plastic.

Samples that were taken at each pit include: (1) general soil parameters, (2) clay minerals, (3) bulk density, (4) Pu 239/240, Am 241, U 233/234, 235, 238, (5) sequential extraction, (6) rad screen, and (7) metals.

4.1.4 Pit Characterization and Soil Sampling Procedures

The same day that each pit was excavated, samples were taken and logged according to RFETS Environmental Management SOP GT.7, "Logging and Sampling of Test Pits, Trenches, and Construction Excavations" procedures. Soil horizons (See Table 4.1.4-1) and discontinuities were identified and photographed at this time. For more information on soil profile descriptions, soil pit characterizations, and micromorphologic features consult Appendix III and "Phase II RFI/RI Report 903 Pad, Mound, and East Trenches Area Operable Unit No. 2 Volume 9 Appendix D - Investigations of Actinide Distribution, Fate and Transport in Soils." When sampling was completed, the soil solution sampling apparatus was installed over a seven to 10 day working period. Daily H&S surveys of the pit area were conducted before the start of work. Installation schematics are shown in Figures 4.1.4-1 through 4.1.4-6.

4.1.5 PIT BACKFILLING AND SITE RESTORATION PROCEDURE

At the conclusion of infiltrometer testing and sampling apparatus installation, the excavated soils were backfilled by horizon. Backfilling procedures followed SOP G.T.7, "Logging and Sampling of Test Pits, Trenches, and Construction Excavations," Section 5.2.4; "Trench Backfilling and Site Restoration." To minimize the destruction of vegetation and disturbance to the instrumentation, the pits were backfilled by hand using shovels and a wheelbarrow. The backfilled soil was lightly watered using a garden-type sprayer to suppress dust and facilitate compaction. Soil was placed

carefully by hand in the areas around the sampling apparatus. When available, grasses and local vegetation were replaced. Garden type mulch was evenly spread on the disturbed areas to aid growth, however, areas above the sampling apparatus were avoided. Several hundred gallons of water were sprayed on the area to encourage recovery of disturbed soils.

Table 4.1.4-1 Soil Depth Profile

Trench TR-1		Trench TR-2		Trench TR-3	
Depth ¹ (cm)	Horizon	Depth ¹ (cm)	Horizon	Depth ¹ (cm)	Horizon
0 – 16	A	0 – 7	A	0 – 18	A
16 – 27	AB	7 – 19	Bw	18 – 35	AB
27 – 58	Btkl	19 – 50	Bt	35 – 51	Bw
58 – 76	Btgk	50 – 105	2Br	51 – 120	Btg, Bth
76 – 103	Btg	105+	3Btgkl	120+	Btgkl
103 – 123+	2Btg				
Trench TR-4			Trench TR-5		
Depth ¹ (cm)	Horizon	Depth ¹ (cm)	Horizon	Depth ¹ (cm)	Horizon
0 – 18	A	0 – 15	A		
18 – 41	Bt1	15 – 48	Bw		
41 – 77	Bt2	48 – 120+	Btg		
77 – 108	Btg				
108+	2BCgkl				
Legend:					
1 Depths were measured from the distance below a cloth measuring tape stretched across the trench face.					

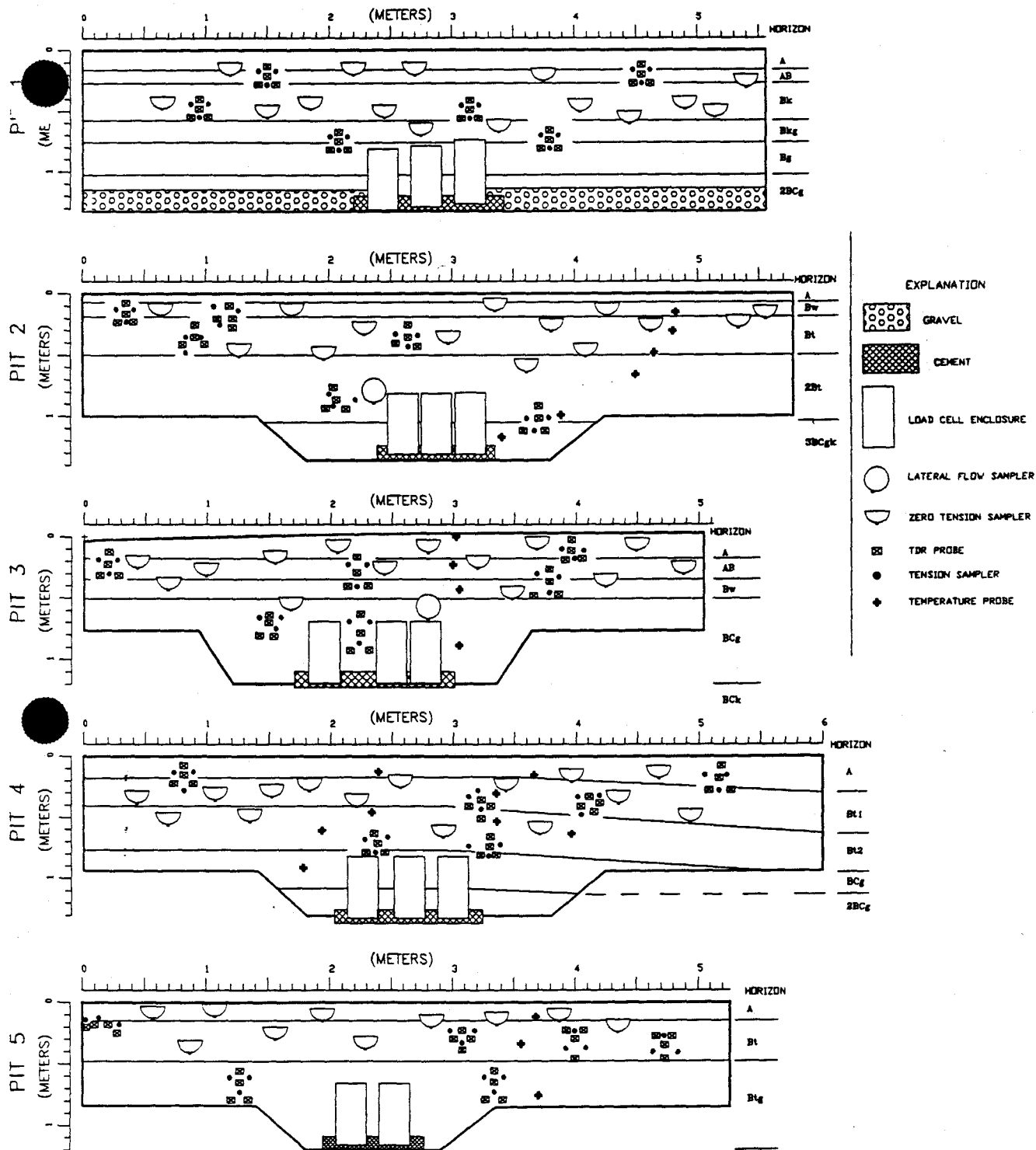


Figure 4.1.4-1 Instrument Location Maps for Pits 1-5

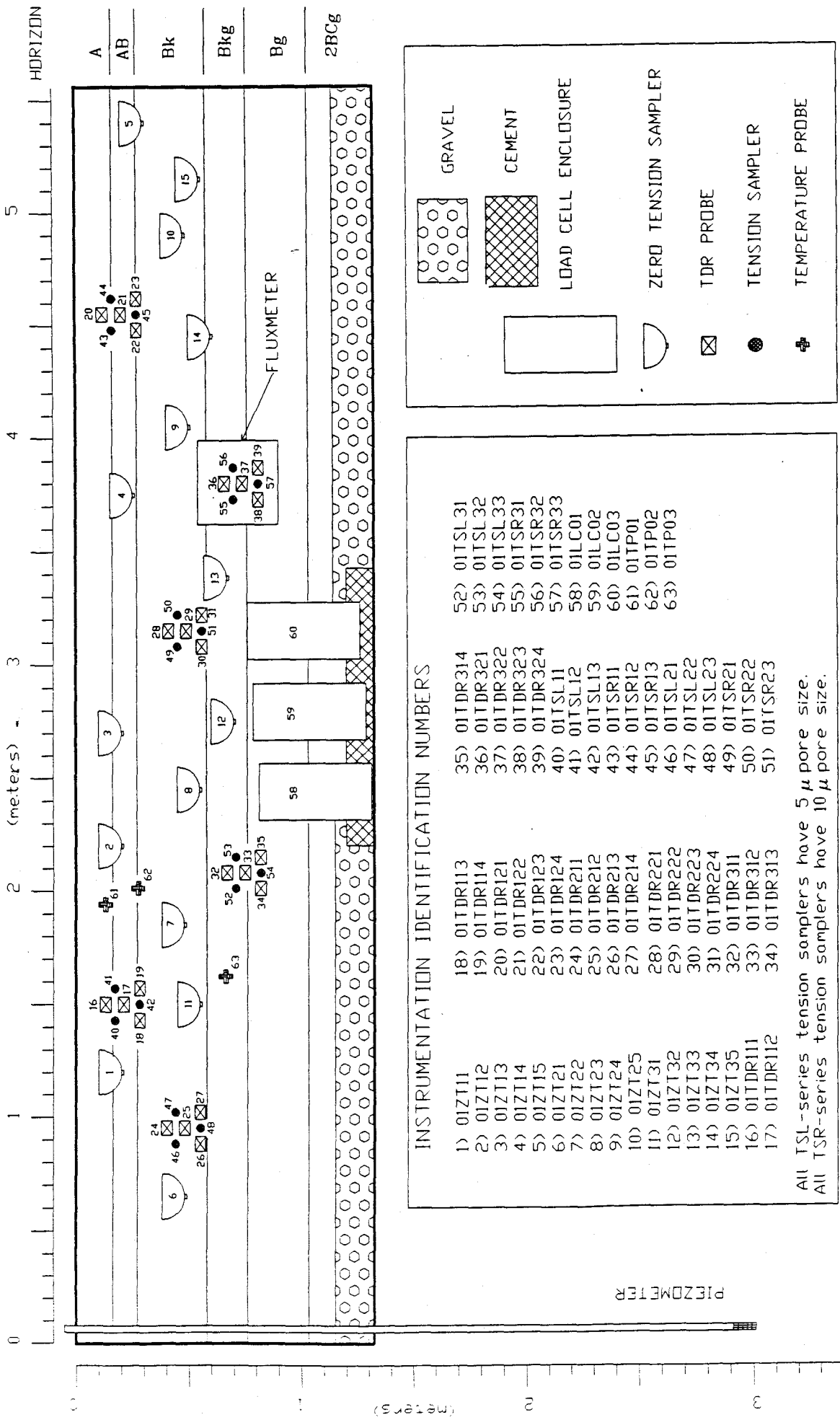


Figure 4.1.4-2 Instrument Location Map: Pit 1 NW Face

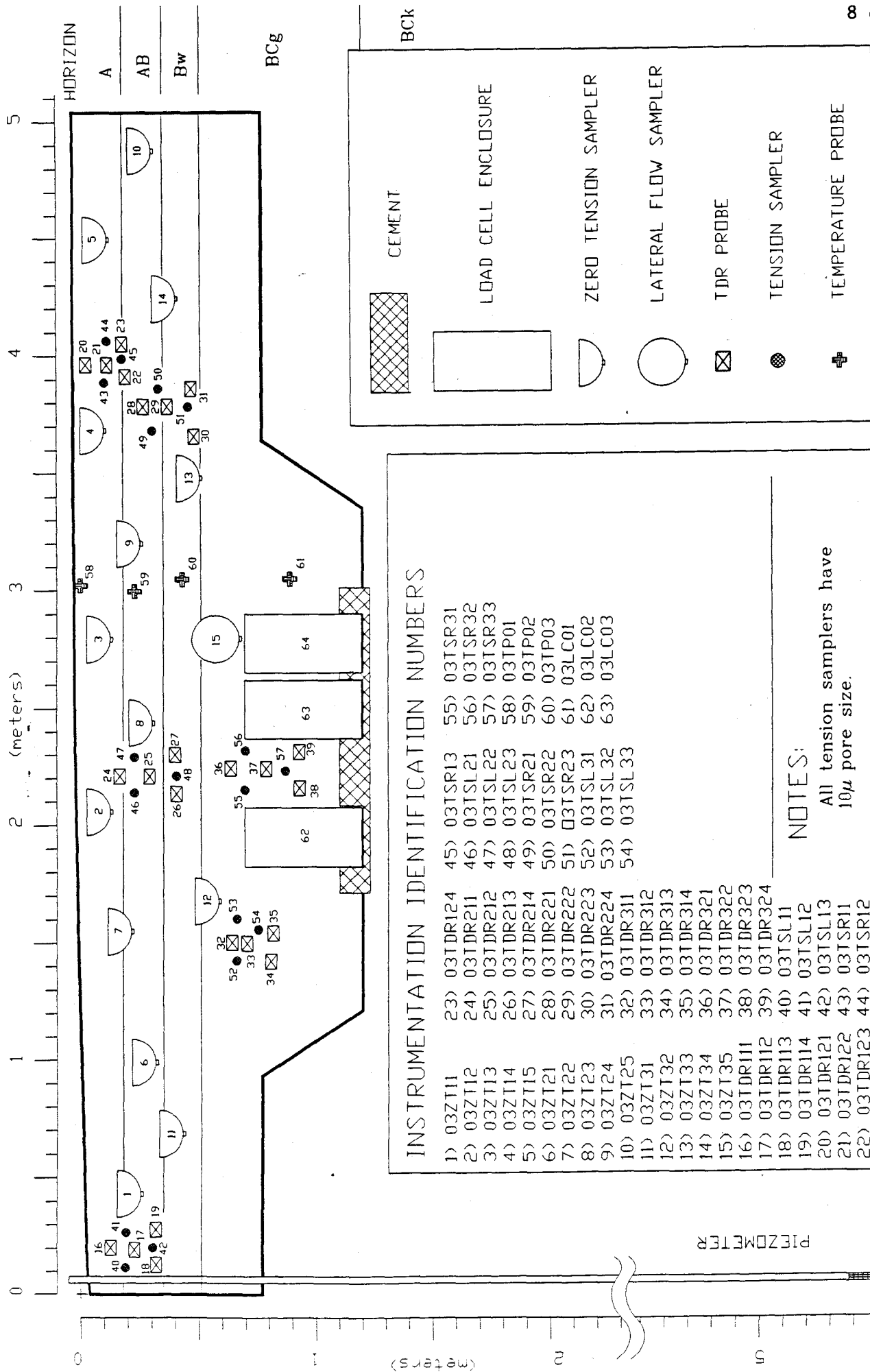


Figure 4.1.4-4 Instrument Location Map: Pit 3 NW Face

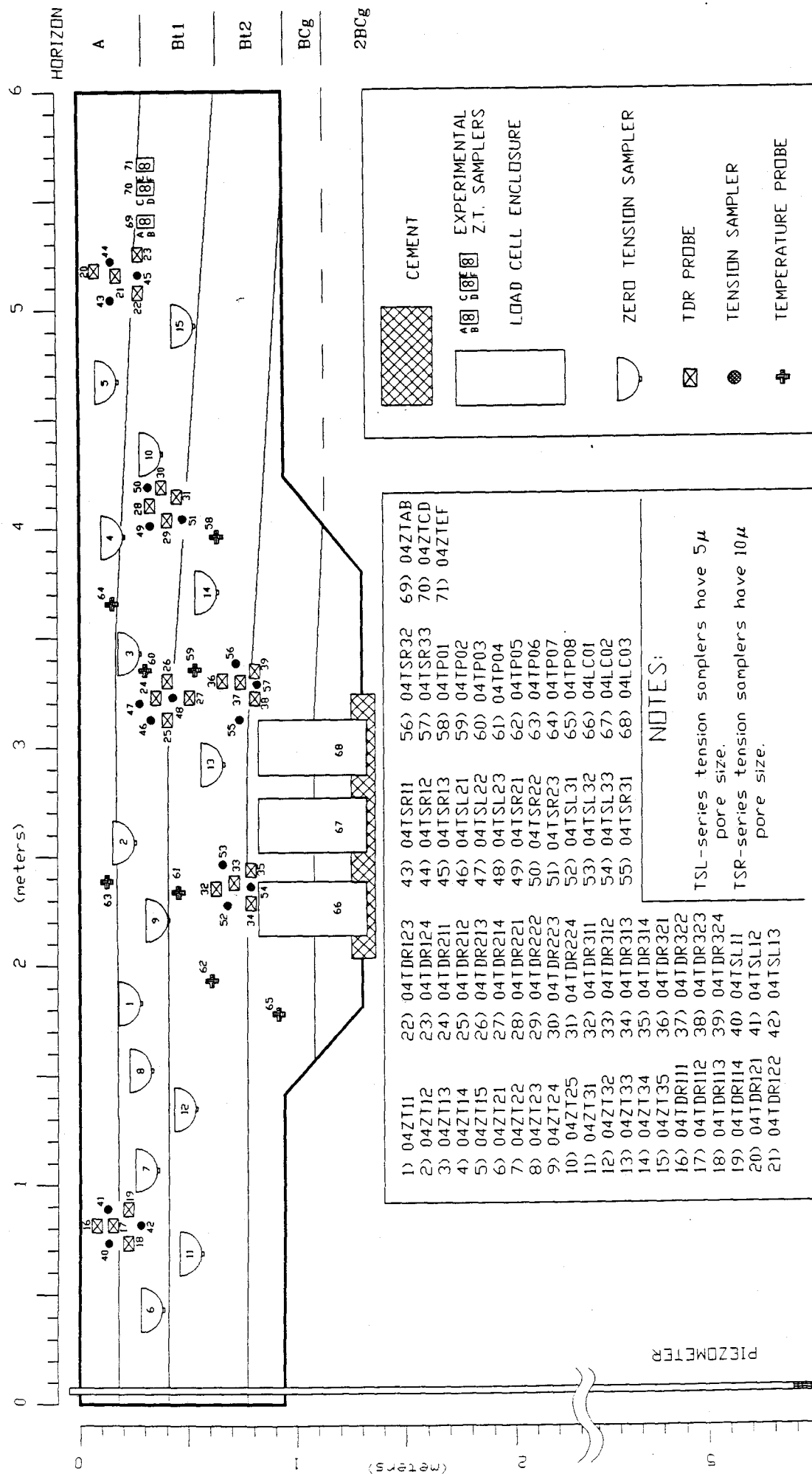


Figure 4.1.4-5 Instrument Location Map: Pit 4 NW Face

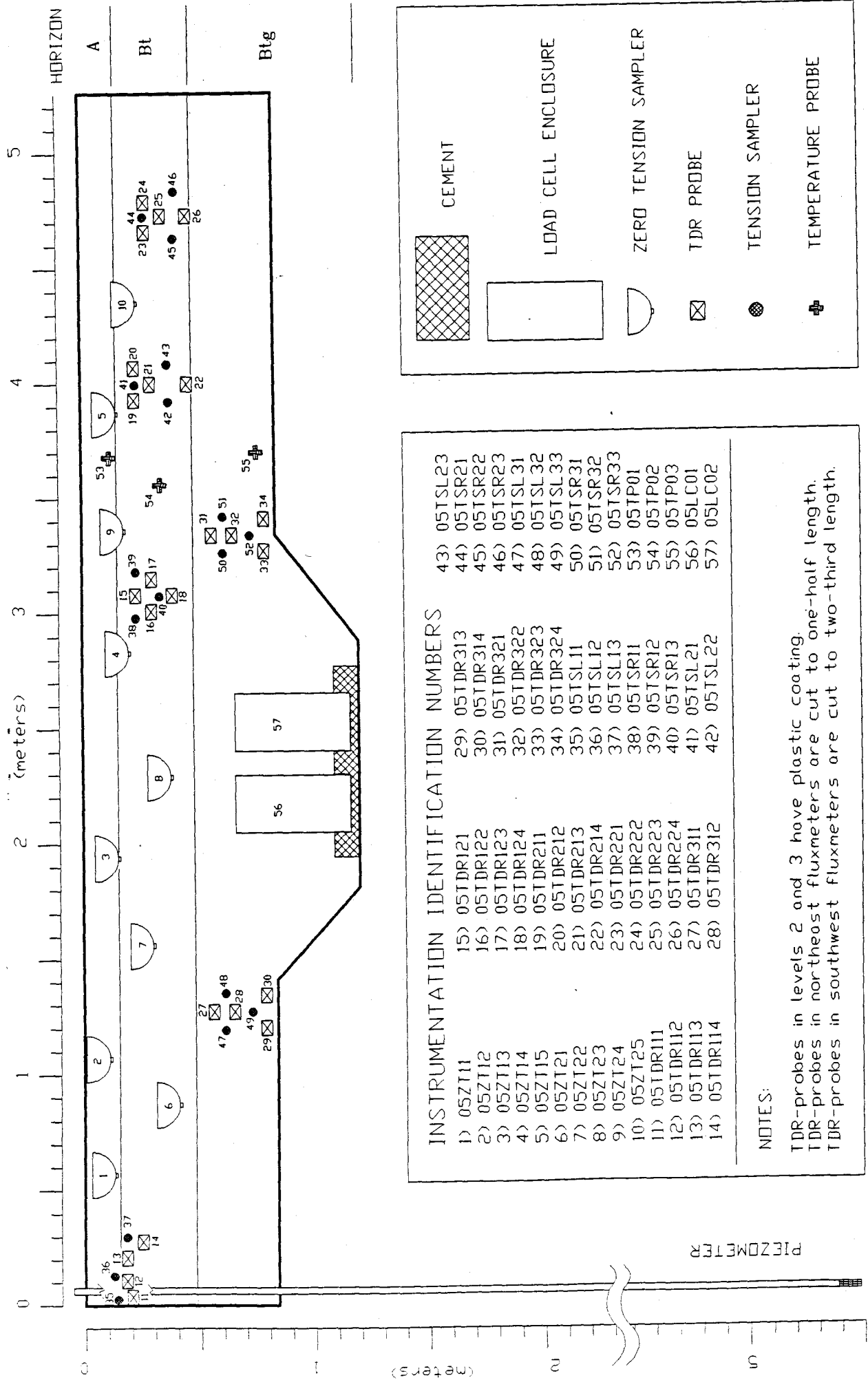


Figure 4.1.4-6 Instrument Location Map: Pit 5 NW Face

4.2 SOIL WATER SAMPLES

4.2.1 Principles of Zero Tension (ZT) Sampler Operation

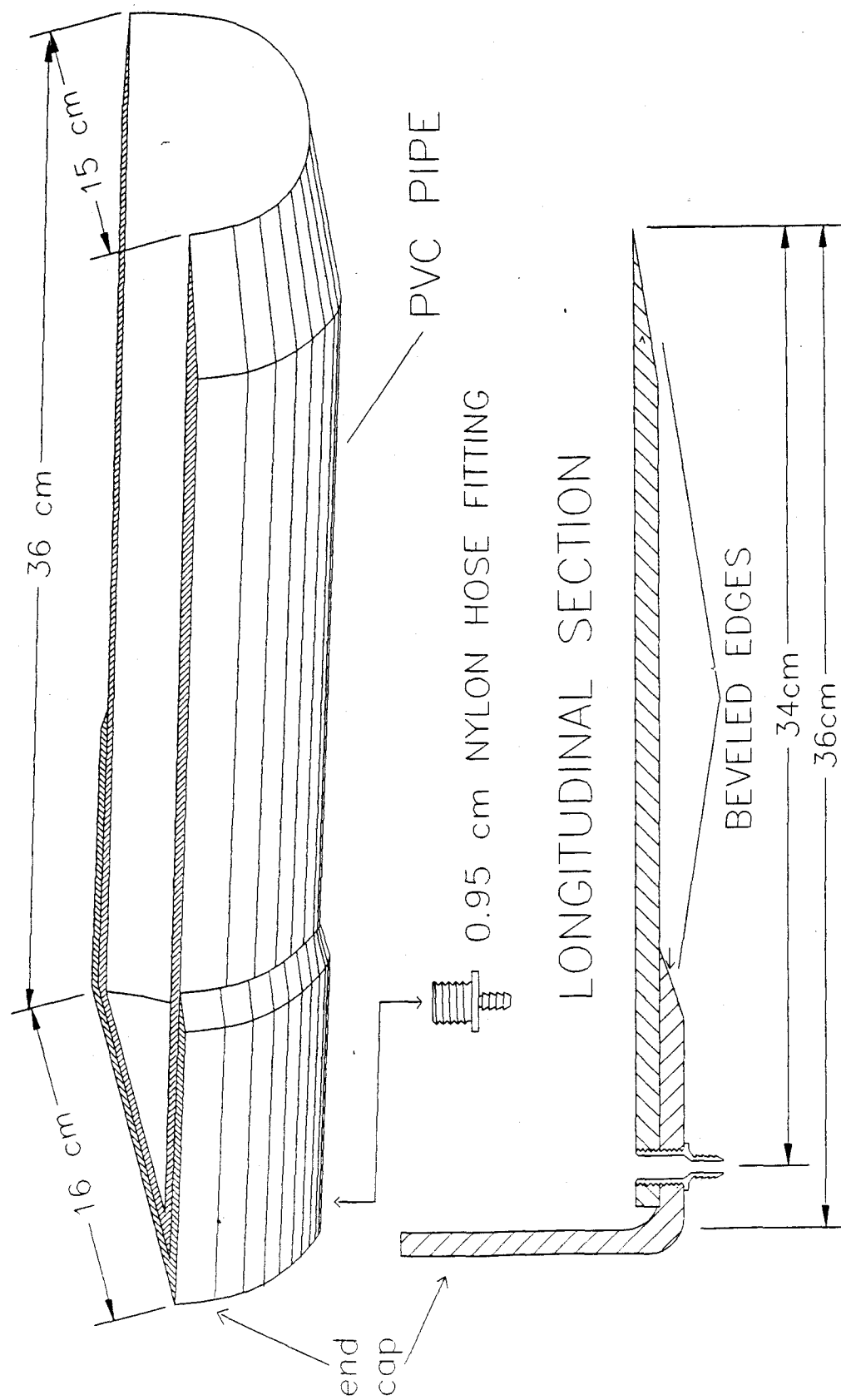
ZT samplers were troughs designed to collect freely flowing water (0-5 kPa matric potential). A sampler consisted of a half-section of 15 cm interior diameter (I.D.) by 30 cm long polyvinylchloride (PVC) pipe capped at one end (See Fig. 4.2.1-1). Water was drained from the sampler through a hole drilled at the capped-end. Tubing connected to a 0.95 cm tubing connector screwed into the hole was used to carry water from the sampler to a collection bottle located downslope from the sampler.

The sampler pipe and end-cap were sharpened at their open ends with a machine grinder, easing the insertion of the sampler into the pit wall. The drain hole was drilled into the end-cap and through the trough midway across the sampler and 25 cm from the sharpened end. It was then tapped and a 0.95 cm I.D. x 1.27 cm long nylon barb fitting was inserted. The hole in the trough was countersunk with a grinding tool (i.e., Dremel). The countersinking assisted in the collection of free flowing interstitial water which reduced the surface tension of water at the fitting.

A lateral flow (LF) ZT sampler was designed to collect horizontally free-flowing water (0-5 kPa matric potential). The sampler was constructed from a 15 cm I.D. x 45 cm long PVC pipe and end-cap. The procedures used for construction, sharpening, and drain hole insertion were essentially the same as for the ZT sampler.

Load cells were used to monitor the amount of water collected over a period of time by the ZT samplers. A load cell is an electronic device used to weigh loads. Water collected by the ZT samplers (25 cm square x 45 cm high) flowed to collection bottles on load cells. A platform attached to the top of the load cell secured a plastic container that holds five-500 ml Nalgene bottles. Polyethylene tubing (0.95 cm I.D.) was attached to the bottom of five ZT samplers along a soil horizon connected to the top of the collection bottles within one enclosure (See Figs. 4.2.1-2 and 4.2.1-3). Each enclosure collected water from a single soil horizon.

OU2 Surficial Soils Sampling Project



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Figure 4.2.1-1 Zero Tension Sampler

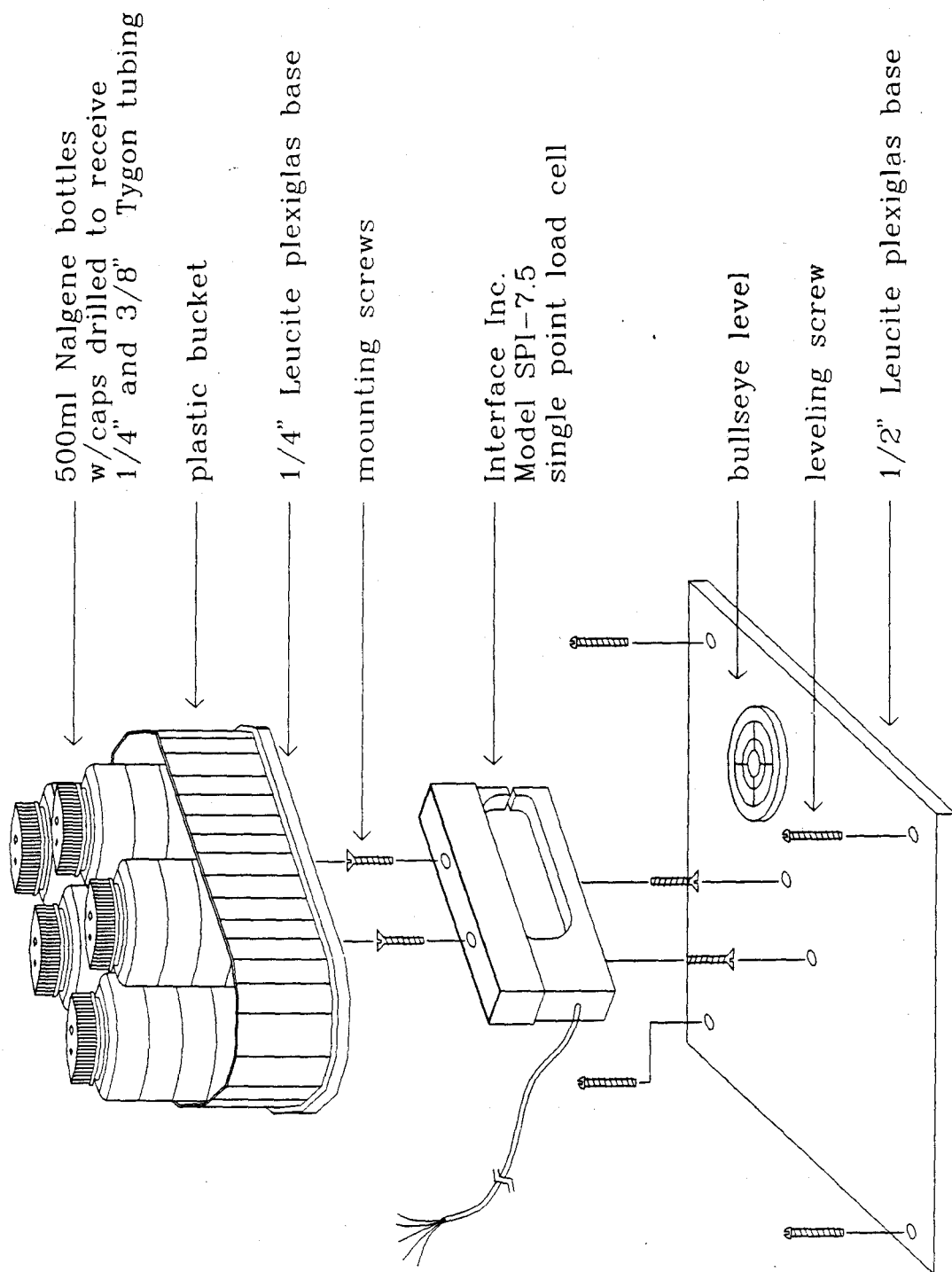


Figure 4.2.1-2 Load Cell Assembly

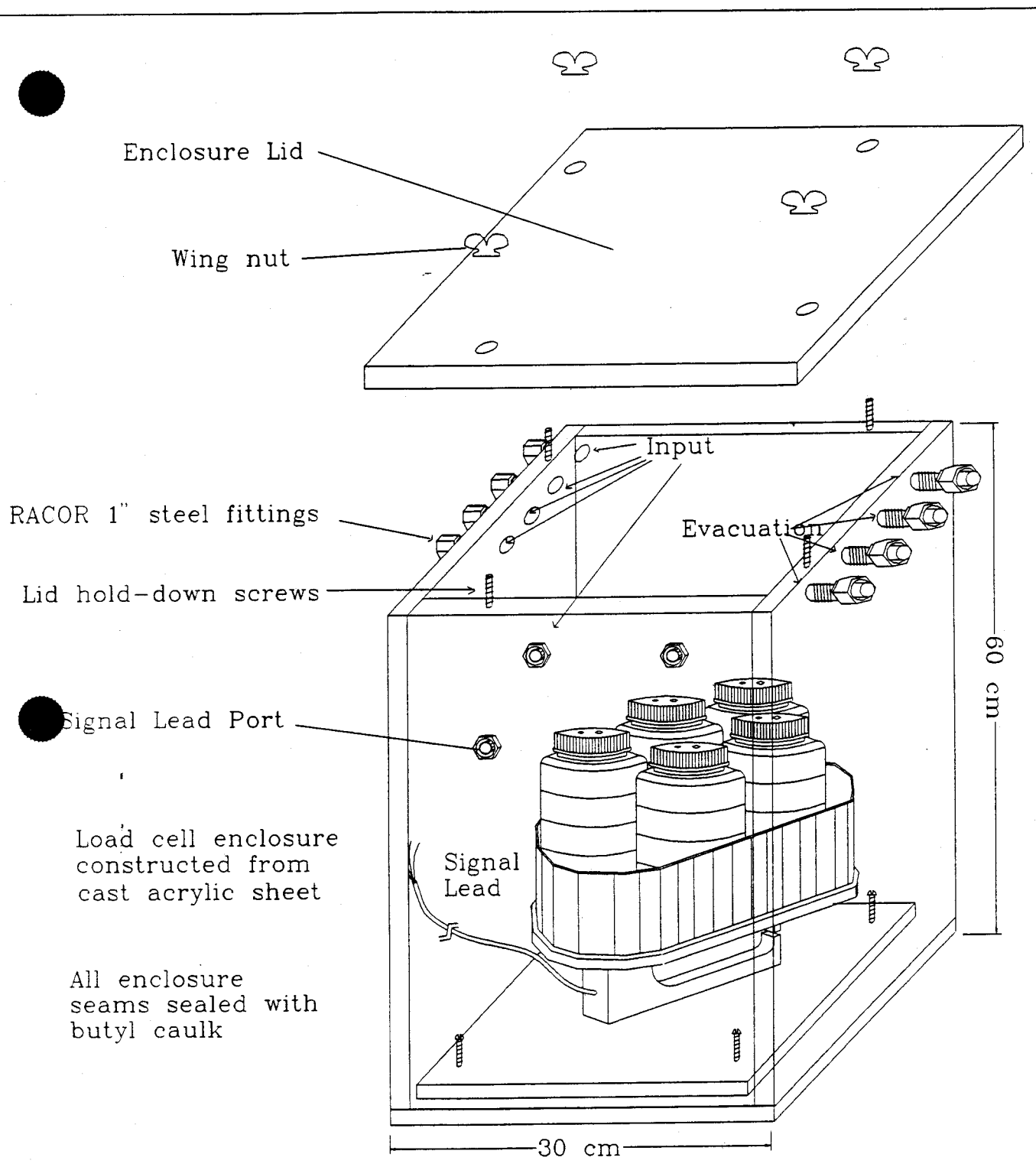


Figure 4.2.1-3 Load Cell Assembly and Enclosure

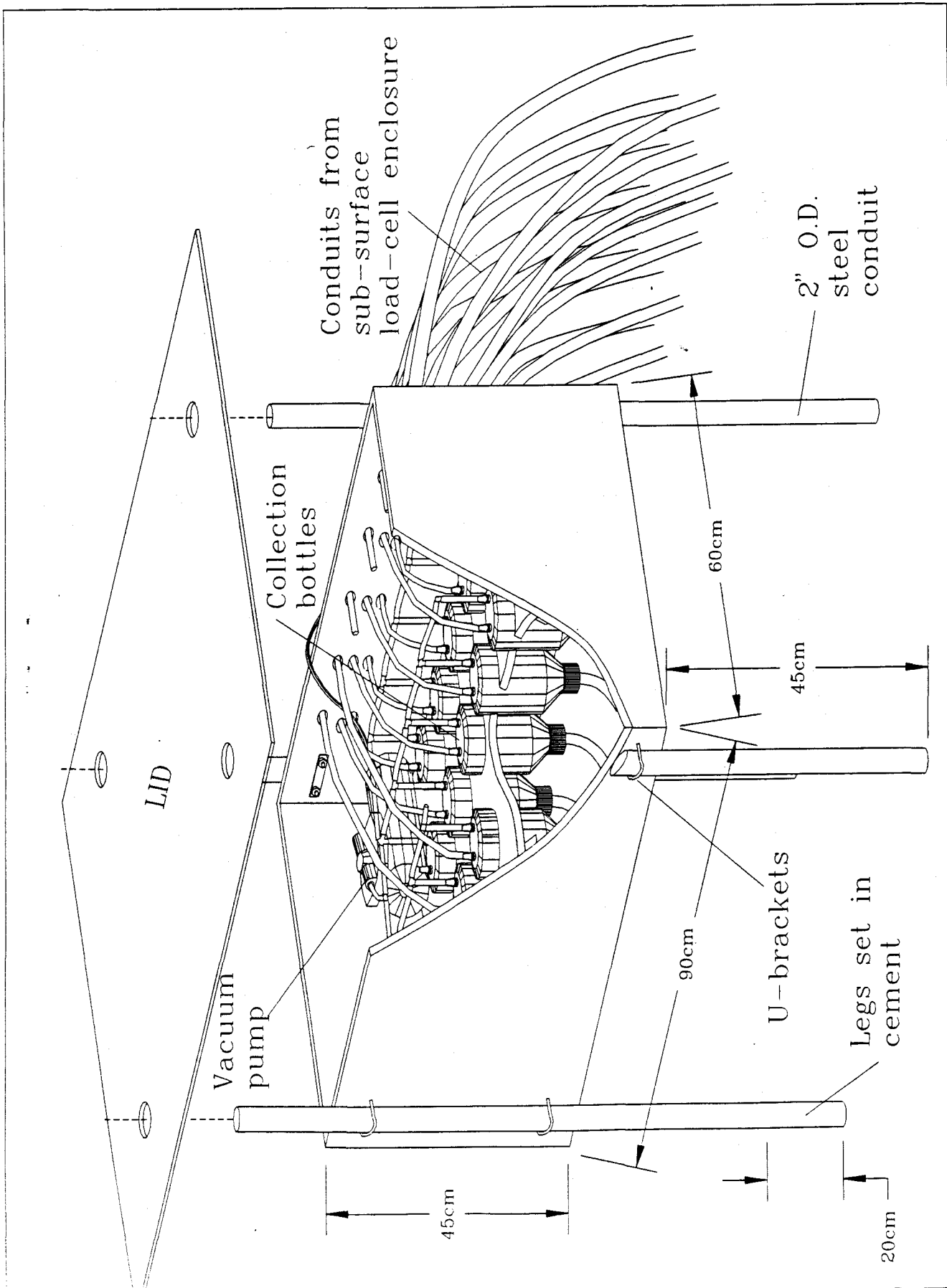


Figure 4.2.1-4 Load Cell Pumping Unit

Three load cell enclosures were located within each pit (except Pit 5 that contained only two). Enclosure locations are shown in Figures 4.1.4-1 through 4.1.4-6. The load cell was connected to a data logger through a multiplexer that continuously monitored the total amount of water collected in the five bottles. Sample collection tubes were also attached to the top of the bottles and extended to the surface where samples were periodically collected using a hand-operated vacuum pump (See Fig. 4.2.1-4). The load cell wiring and polyethylene tubing that passed through the plexiglass enclosure were secured and protected using 1.9 cm I.D. watertight fittings and flexible conduit. The protective sample collection conduit that extended to the surface was also protected with a section of 5.08 cm I.D. PVC pipe.

4.2.2 ZT Sampler Installation

Five ZT samplers were installed within each soil horizon. Before field installation, the sampler was submitted to a high pressure decontamination wash and stored in plastic. A hand-operated hydraulic jack was used to install the ZT samplers. The hydraulic jack unit consisted of a hand-operated pump and ram section. A 1 m long hydraulic line connected the pump to the ram. The ram section consisted of a hydraulic jack with interchangeable extensions of various length. Installation of the ZT samplers required three field personnel, two technicians within the pit and one PI outside. While one technician operated the pump and the other held the ram and extension, the PI supported and directed the ZT installation into the pit wall. Wooden bracing was placed along the opposite pit wall to protect the areas scheduled for hydraulic conductivity testing and to brace the ram section. At Pit 5, large cobbles prevented the placement of ZT samplers within the third soil horizon. LF ZT samplers were installed in Pits 2 and 3 in place of the middle ZT in the third horizon. The ZT samplers' relative locations within each pit are listed in Tables 4.2.2-1 through 4.2.2-5 and are shown in Figures 4.1.4-1 through 4.1.4-6.

Three experimental ZT samplers were also installed at Pit 4. They were received from Michael Thompson of Iowa State University. The samplers' alphanumeric designation were 04ZTA, 04ZTB, and 04ZTC. Their installed locations are listed in Table 4.2.2-6 and shown in Figure 4.1.4-5.

Table 4.2.2-1 Trench TR-1 Zero Tension Samplers

Trench TR-1					
Designation	Location		ZT Sampler Dimensions		
	Depth ¹ (cm)	Distance ² (cm)	Length ³ (cm)	Width ³ (cm)	Area ⁴ (cm ²)
First Horizon					
01ZT11	20	120	36.0*	15.0*	540.0*
01ZT12	20	220	36.0*	15.0*	540.0*
01ZT13	20	270	36.0*	15.0*	540.0*
01ZT14	25	375	36.0*	15.0*	540.0*
01ZT15	30	540	36.0	15.0	540.0
Second Horizon					
01ZT21	48	65	36.0*	14.7*	529*
01ZT22	48	185	36.0*	14.7*	529*
01ZT23	55	245	36.0	14.7	529.2
01ZT24	50	405	36.0	14.7	529.2
01ZT25	48	470	35.8	14.8	529.8
Third Horizon					
01ZT31	55	150	36.0*	15.0*	540.0*
01ZT32	70	275	36.0*	15.0*	540.0*
01ZT33	67	335	36.0	15.0	540.0
01ZT34	60	445	36.0*	15.0*	540.0*
01ZT35	55	515	36.0	15.0	540.0
Legend:					
1 Depths were measured from the distance below a cloth measuring tape stretched across the trench face.					
2 Distances were measured from a fixed stake at the far left side of trench.					
3 Sampler Inner Dimension.					
4 Surface area exposed to vertical water flow = Length x Width.					
• Approximate					

Table 4.2.2-2 Trench TR-2 Zero Tension Sampler

Trench TR-2					
Designation	Location		ZT Sampler Dimensions		
	Depth ¹ (cm)	Distance ² (cm)	Length ³ (cm)	Width ³ (cm)	Area ⁴ (cm ²)
First Horizon					
02ZT11	17.8	63.5	35.5	14.9	529.0
02ZT12	17.8	170.2	35.7	14.8	528.4
02ZT13	14.0	325.3	35.4	15.1	534.5
02ZT14	17.8	426.7	35.5	14.9	529.0
02ZT15	20.3	505.5	35.7	14.9	531.9
Second Horizon					
02ZT21	33.0	228.6	35.5	14.9	529.0
02ZT22	40.6	297.2	35.7	14.8	528.4
02ZT23	30.5	381.0	35.7	15.0	535.5
02ZT24	30.5	462.3	35.6	14.8	526.9
02ZT25	27.9	533.4	35.7	14.6	521.2
Third Horizon					
02ZT31	50.8	127.0	35.4	14.9	527.5
02ZT32	53.3	195.6	35.5	15.2	539.6
02ZT33	78.7	236.2	35.5*	15*	532.5*
02ZT34	63.5	360.7	35.7	14.9	531.9
02ZT35 ⁵	50.8	408.9	36.3	14.9	174.4
Legend: 1 Depths were measured from the distance below a cloth measuring tape stretched across the trench face. 2 Distances were measured from a fixed stake at the far left side of trench. 3 Sampler Inner Dimension. 4 Surface area exposed to vertical water flow = Length x Width. 5 LF designates lateral flow type sampler. Width = Inner Diameter. Area = πr^2					
* Approximate					

Table 4.2.2-3 Trench TR-3 Zero Tension Sampler

Trench TR-2					
Designation	Location		ZT Sampler Dimensions		
	Depth ¹ (cm)	Distance ² (cm)	Length ³ (cm)	Width ³ (cm)	Area ⁴ (cm ²)
First Horizon					
03ZT11	25.4	43.2	35.5	15.0	532.5
03ZT12	12.7	205.7	35.7	15.1	539.1
03ZT13	12.7	279.4	35.9	15.0	538.5
03ZT14	10.2	368.3	36.0	15.2	547.2
03ZT15	11.4	449.6	36.0	14.8	532.8
Second Horizon					
03ZT21	31.8	99.1	35.5	15.1	540.6
03ZT22	21.6	154.9	35.7	15.0	535.5
03ZT23	30.5	243.8	35.7	16.0	571.2
03ZT24	25.4	320.0	35.8	14.9	533.4
03ZT25	30.5	487.7	35.8	15.6	558.5
Third Horizon					
03ZT31	43.2	68.6	35.6	15.6	555.4
03ZT32	58.4	167.6	35.7	15.0	535.5
03ZT33	57.2	279.4	35.7	15.2	542.6
03ZT34	50.8	348.0	35.8	15.1	540.6
03ZT35 ⁵	40.6	424.2	45.5	14.9	174.4
Legend: 1 Depths were measured from the distance below a cloth measuring tape stretched across the trench face. 2 Distances were measured from a fixed stake at the far left side of trench. 3 Sampler Inner Dimension. 4 Surface area exposed to vertical water flow = Length x Width. 5 LF designates lateral flow type sampler. Width = Inner Diameter. Area = πr^2					

Table 4.2.2-4 Trench TR-4 Zero Tension Sampler

Trench TR-2					
Designation	Location		ZT Sampler Dimensions		
	Depth ¹ (cm)	Distance ² (cm)	Length ³ (cm)	Width ³ (cm)	Area ⁴ (cm ²)
First Horizon					
04ZT11	27.9	182.9	35.8	14.7	526.3
04ZT12	25.4	256.5	35.7	14.6	521.2
04ZT13	27.9	342.9	35.6	14.9	530.4
04ZT14	20.3	396.2	35.7	14.9	531.9
04ZT15	17.8	467.4	35.8	14.9	533.4
Second Horizon					
04ZT21	38.1	43.2	35.8	14.8	529.8
04ZT22	35.6	106.7	35.5	15.0	532.5
04ZT23	33.0	152.4	35.7	14.8	528.4
04ZT24	40.6	221.0	35.6	14.9	530.4
04ZT25	38.1	434.3	35.7	14.8	528.4
Third Horizon					
04ZT31	55.9	68.6	35.7	14.9	531.9
04ZT32	53.3	134.6	35.8	14.8	529.8
04ZT33	66.0	292.1	35.8	14.8	529.8
04ZT34	63.5	370.8	35.8	14.7	526.3
04ZT35	53.3	492.8	35.6	14.9	530.4
Legend: 1 Depths were measured from the distance below a cloth measuring tape stretched across the trench face. 2 Distances were measured from a fixed stake at the far left side of trench. 3 Sampler Inner Dimension. 4 Surface area exposed to vertical water flow = Length x Width.					

Table 4.2.2-5 Trench TR-5 Zero Tension Sampler

Trench TR-2					
Designation	Location		ZT Sampler Dimensions		
	Depth ¹ (cm)	Distance ² (cm)	Length ³ (cm)	Width ³ (cm)	Area ⁴ (cm ²)
First Horizon					
05ZT11	13	57	35.7	15*	536*
05ZT12	11	107	36*	15*	540*
05ZT13	15	194	36*	15*	540*
05ZT14	20	283	36*	15*	540*
05ZT15	15	387	36*	15*	540*
Second Horizon					
05ZT21	44	87	35.7	15*	536*
05ZT22	30	156	36*	15*	540*
05ZT23	38	229	36*	15*	540*
05ZT24	18	336	36*	15*	540*
05ZT25	24	435	36*	15*	540*
Legend:					
1 Depths were measured from the distance below a cloth measuring tape stretched across the trench face.					
2 Distances were measured from a fixed stake at the far left side of trench to the drain on each zero tension sampler.					
3 Sampler Inner Dimension.					
4 Surface area exposed to vertical water flow = Length x Width.					
• Approximate					

Table 4.2.2-6 Experimental ZT Samplers

Trench TR-4		
Designation	Depth ¹ (cm)	Distance ² (cm)
04ZTA	30.5	541.0
04ZTB	33.0	541.0
04ZTC	30.5	556.0
Legend:		
1 Depths were measured from the distance below a cloth measuring tape stretched across the trench face.		
2 Distances were measured from a fixed stake at the far left side of trench.		

Tables 4.2.2-1 through Table 4.2.2-5 contain ZT sampler alphanumeric designations, pit location, depth, distance, and sampler collection surface area. Samplers were designated by horizon,

sampler type, horizon, and location. (i.e., 01ZT25 designates Pit 1, ZT sampler, second horizon, fifth location).

The Interface, Inc. Model SPI-7.5 single point load cell has a rated capacity of 3.4 kg. Each load cell rated calibration (Output, Compression = mV/V) was checked by comparing output voltage (mV) to direct gravitational measurement (gm) using an electronic balance Mettler Model PM6100. This procedure was performed with a 12 volt/675 amp deep-cycle (DC) battery attached to a load cell. The battery (i.e., excitation) voltage (V) was measured with a voltmeter. The mV from the load cell was measured for a variety of applied weights. The calibrated weight (mV) was then determined by multiplying the load (gm) by the rated maximum output at the excitation (battery) voltage (mV). Manufacturer serial numbers along with their rated calibration values are listed in Table 4.2.2-7. Manufacturer calibration verification sheets and pre-installation calibration worksheets with corresponding graphs are included in Appendix IV.

Table 4.2.2-7 Load Cell Calibrations

Load Cells			
Serial Number	Output mV/V at 3.4 kg and 10V	Serial Number	Output mV/V at 3.4 kg and 10V
C16353	3.127	C16380	3.119
C16355	3.133	C16381	3.161
C16359	3.128	C16383	3.162
C16360	3.242	C16386	3.177
C16364	3.163	C16387	3.207
C16373	3.106	C16396	3.164
C16374	3.114	C16398	3.160
C16375	3.151		

After the pit was characterized and sampled, a concrete pad (1 m wide x 3 m long x 0.15 m deep) was emplaced at the center of the pit. The bottoms of the enclosures were placed into the concrete and leveled using a bulls-eye level. An additional six to 10 cm of concrete was placed along the sides and between the enclosures. The concrete pad was used to permanently stabilize the load cell enclosures.

4.2.3 ZT Sampler Data

The sampling of interstitial water shall follow guidelines set forth in EMD SOP GT.20; "Procedures for Soil Interstitial Water Sampling and Sampler Installation," EMD Manual Operation SOP, Rev. 2; Dated: March 1, 1992. Section 9.0, "Collection of Interstitial Waters."

Pre-installation load cell calibration information and data is presented in Appendix IV. The electronic version of the load cell calibration data is contained on the SSG_SNBK Bernoulli data diskette. See Appendix X, 'Loadcell Calibration Data Location' for details.

4.2.4 ZT Sampler Problems and Solutions

Over fifty data points were used to find the relationship between the milliVolt/Volt output of the load cells and the corresponding amount of water weighed by the load cell. The data was gathered during 1993 (Julian Days 84 - 207). Each data point was dependent on three factors: (1) the volume of water collected, (2) the milliVolt/Volt value just after the previous sampling period (called the baseline reading), and (3) the milliVolt/Volt value just before the current water collection (called the final reading). The baseline reading was subtracted from the final reading to give the change in milliVolts/Volt which was then compared to the volume of water collected.

Although there were 111 data points available for analysis, about sixty were considered invalid due to insufficient data. All data points from the first sampling were omitted because a baseline reading had not been established. Many readings taken during the rain simulations were also invalid because no baseline reading could be established. Rain simulations would usually begin immediately after the load cells had been drained for sampling. This practice hindered an accurate baseline reading because the load cells were monitored every 1.5 hours by the datalogger. Therefore, the "baseline" reading could occur up to 1.5 hours into the rain simulation, allowing sufficient time for water to flow to the load cells and deviate the baseline reading. Occasionally, the load cell would not function properly, giving a systematic error reading of -6999, thus preventing the establishment of a baseline and final reading. System failure primarily resulted from faulty wiring, environmental degradation of the equipment, insufficient battery voltage, internal failure of the multiplexors and possibly the load cells.

The correlation for all load cells is shown in Figure 4.2.4-1. A least squares fit line ($y = .573x$; $r^2 = .57$) was calculated for the data points. When no water enters the load cell, there is no increase in the load cell reading; hence, the y-intercept for the least squares line is zero.

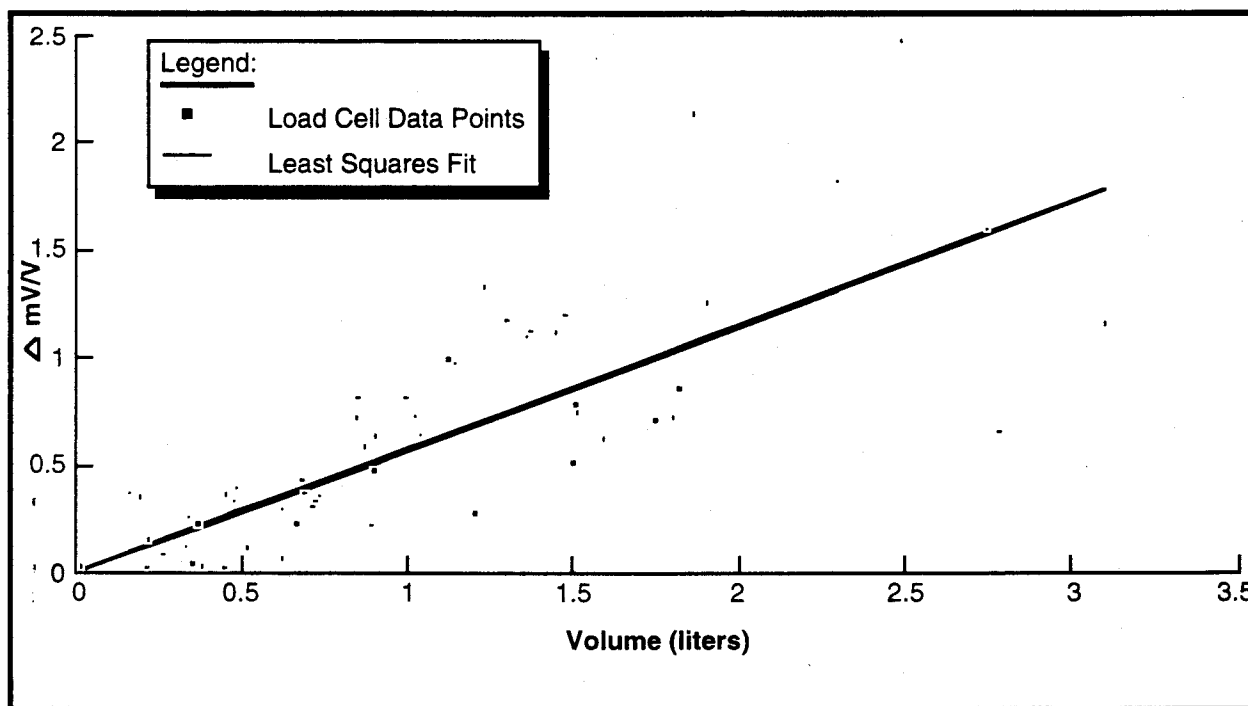


Figure 4.2.4-1 Correlation for All Load Cells

To obtain valid data points in the future, reliable baseline and final readings must be obtained. Rain simulations should start only after the datalogger has executed at least one cycle. System errors need to be minimized before sampling occurs by weather-proofing the equipment and checking all connections periodically. Battery voltage must be maintained in the 12 to 13 volt range by installing an additional solar panel for each battery. Accurate records need to be kept to show when sampling occurred according to the datalogger clock.

4.2.5 Principles of Tension Soil Solution Sampler (TSSS) Operation

TSSS, also known as pressure vacuum lysimeters, consisted of hollow, porous cylinders (5- μ m and 10- μ m pore size) made of polyethylene tetrafluoride (PTFE) (i.e., Teflon) connected to 0.16

TENSAM1.DWG

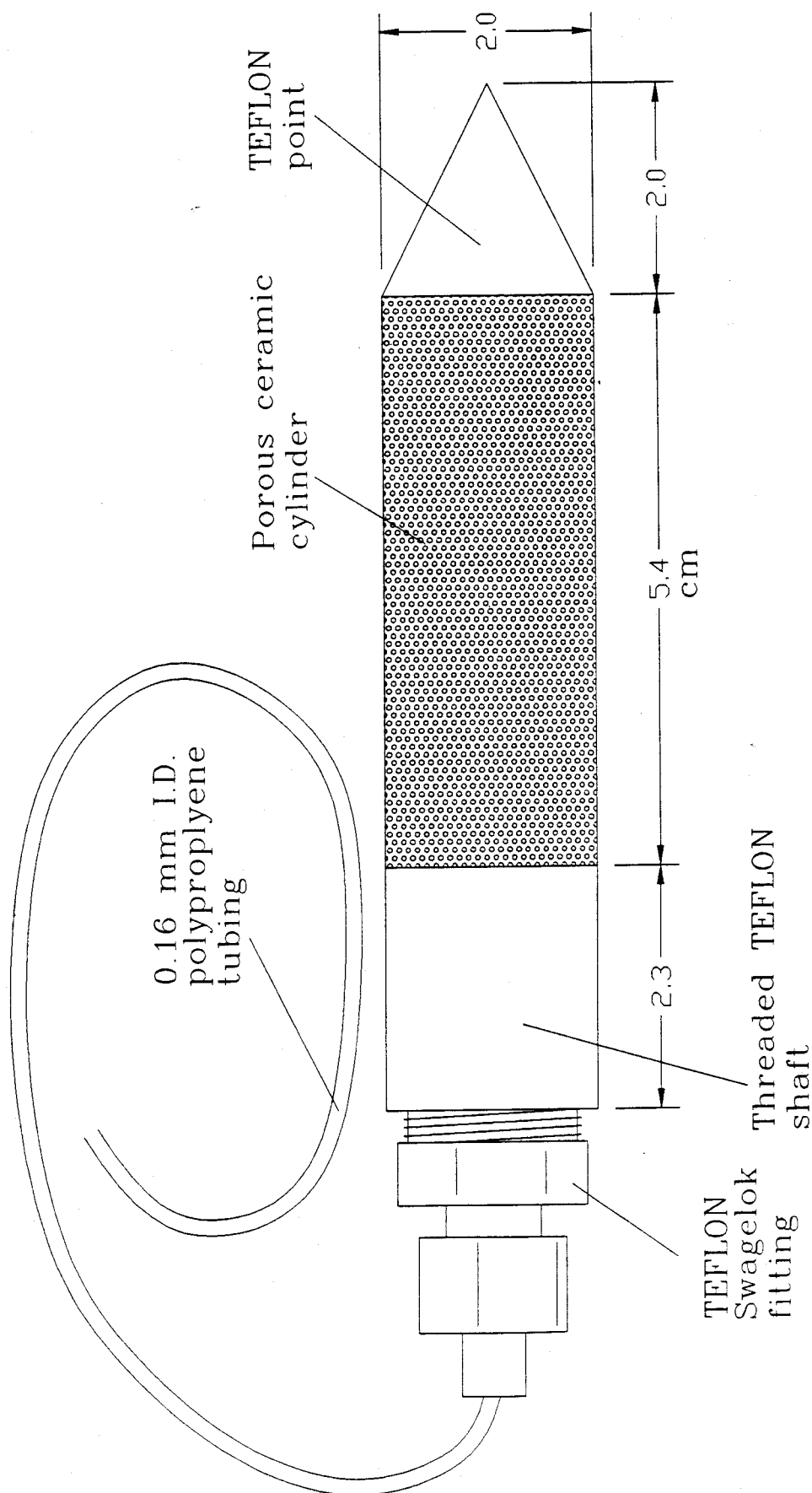


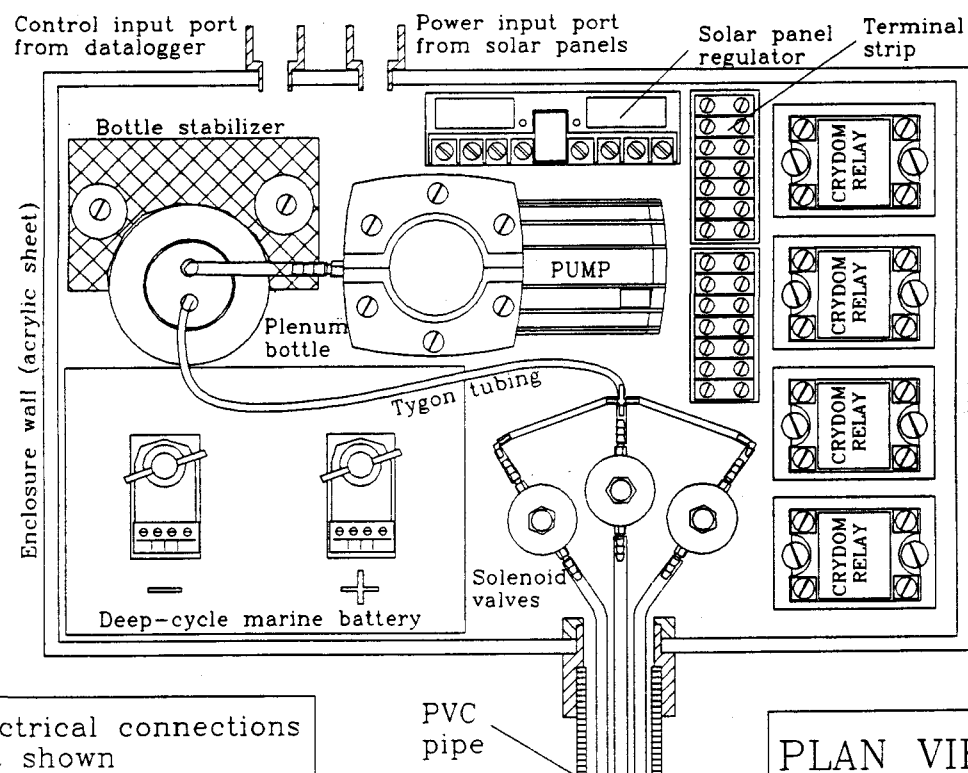
Figure 4.25-1 Tension Sampler

cm I.D. polyethylene tubing (See Fig. 4.2.5-1). A TSS sampler collected soil solution at higher matric potentials (i.e., 5-40 kPa) than ZT samplers. Water samples were obtained by applying suction (i.e., vacuum) to the sampler through the polyethylene tubing. Before installation, each TSSS was immersed into a thin silica flour slurry (water:soil = 10:1) where a vacuum was applied for a minimum of 15 minutes. This process filled the biggest pores of the sampler with small silica particles, that increased capillary contact between soil and sampler. Thus, its' hydrophobicity was reduced. The manufacturers' information on the TSSS is included in Appendix V.

4.2.6 TSSS Installation and Calibration

The automated tension sampler (TS) collection system consisted of: (1) a vacuum pump enclosure that contained a pump, 12V DC battery, and controls; (2) an insulated box that contained the sample collection vessels, and (3) three 18-Watt photovoltaic panels used to recharge the 12-volt battery (See Fig. 4.2.6-1). The high vacuum pump enclosure (61 cm long x 35 cm wide x 51 cm high) was constructed of 1.3 cm thick, clear plexiglass that was joined with an acrylic cement. The vacuum system consisted of a 7.0-amp diaphragm-type vacuum pump, 12-volt/675-amp marine battery, 3-solenoids, 4-solid state relays mounted onto two heat sinks, one in-line 10-amp fuse, a terminal strip, and a single 1000 ml glass bottle that functions as a plenum for the vacuum system and as an overflow collection vessel. All of these were mounted on 2 cm thick plywood. The insulated box consisted of a 61 cm long x 30 cm wide x 30 cm high cooler that contained six 1000 ml sample collection vessels.

Each vessel collected the water drawn from a separate cluster. The vacuum enclosure was connected to the insulated box with a 46 cm length of 3.8 cm I.D. PVC pipe. The pipe was used to cover the 0.95 cm I.D. polyethylene tubing that ran from the vacuum box to the insulated box. Three photovoltaic panels (SOLAREX Model MSX-18R) were mounted onto a wooden structure at the end of each pit to automatically recharge the battery. The orientation of the three solar panels were 45, 50; 90, 50; 135, 50 and faced southeast, south, and southwest, inclined approximately 50 degrees from horizontal. The tubing and wiring connections to the vacuum enclosure were protected from the weather and wildlife with 1.3 cm I.D. flexible conduit.



THERMO-BOX

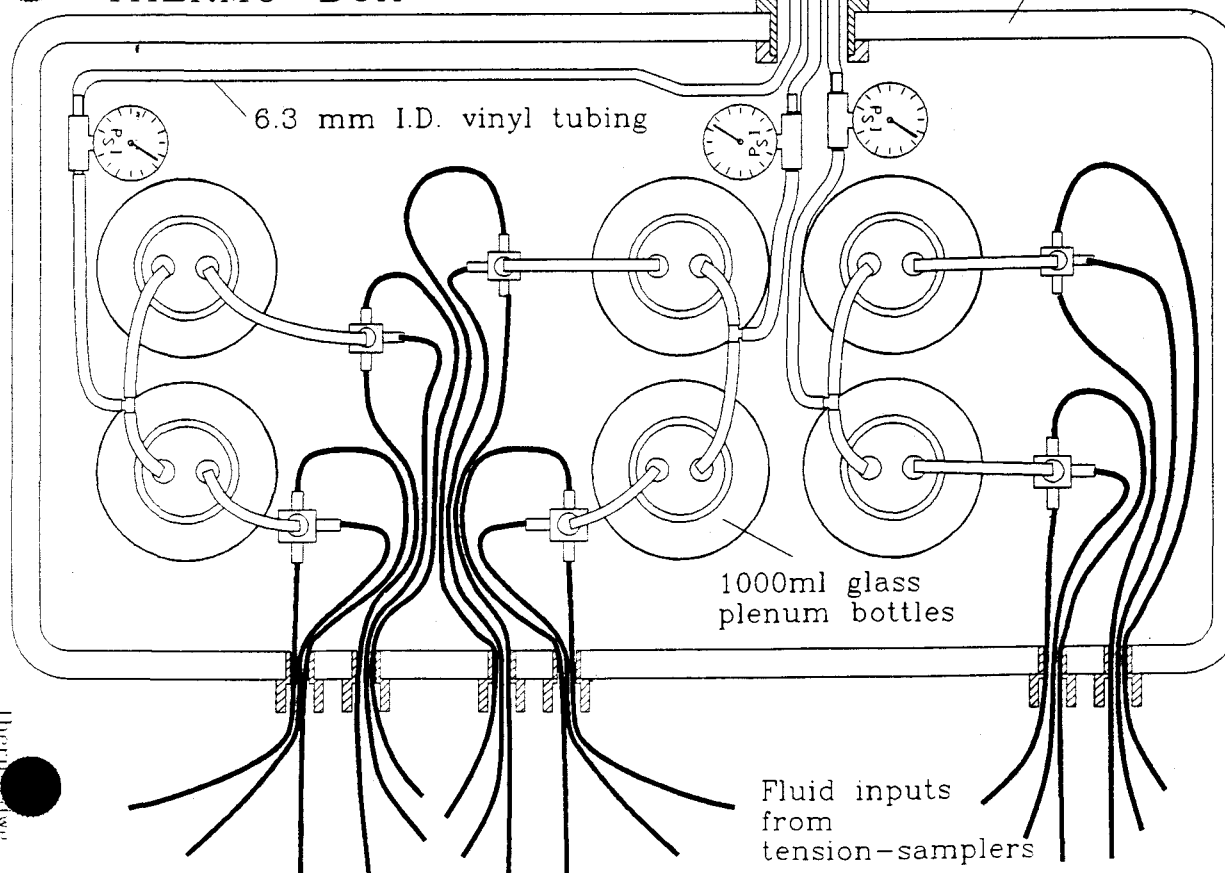


Figure 4.26-1 Tension Sampler Pumping Assembly: Plan View

4.2.7 Clusters

A cluster (previously referred to as a fluxmeter) consisted of three components: (1) three TSs, (2) four Time Domain Reflectometry (TDR) moisture probes, and (3) the TS collection system. The 5 or 10 μm TSs were first installed into the pit wall. Four TDR probes (a TDR probe consisted of two wave guides) were placed and then connected to twin cable leads. Two clusters were installed into each soil horizon.

A TS (a hollow, porous cylinder made of Teflon) was attached to a vacuum source. When a vacuum was applied, water was sucked from the soil through the porous cylinder into a collection vessel. Before installation, the TSs were saturated in distilled water for a minimum of thirty minutes.

To install the TSs, a clean soil core sampling tool (SoilMoisture Equipment Corp., Model 200-A) was driven into the pit wall using a slide hammer. The soil core was placed into a plastic tub where distilled water was added to make a slurry. The TS was placed into the core-hole and filled with the slurry. To install the wave guides, a spare 30 cm guide was hammered into the pit wall then removed leaving a shaft into which the wave guide was pressed. The twin lead of the TDR cable was then connected to corresponding pairs of wave guides. The tension sampler tubing was then inserted into 1.9 cm I.D. flexible conduit for protection. The TDR cable was protected by placing it into 5.08 cm I.D. PVC pipe. The TDR cables were connected to a cable tester through three levels of multiplexors.

Tables 4.3.1-1 through 4.3.1-5 in Section 4.3.1 list the installed locations for the TS and TDR probes, pore size of the tension sampler, and TDR probe length. It also notes if the TDR wave guides are covered with electrical shrink tubing. The TS alphanumeric designation denotes pit number, TS, pore size (05 or 10 designating 5 or 10 μm , respectively), and cluster location (1 or 2, designating left or right, respectively). The TDR probe alphanumeric designation denotes pit number, TDR, horizon, cluster location and probe number (i.e., 1, 2, 3, or 4). For example: 03TDR223 represents Pit 3, TDR, Horizon 2, Location 2, Probe 3. The column listing "Covered" registers whether or not the TDR probe was covered with electrical shrink tubing.

4.2.8 TSSS Problems and Solutions

The TSs had a consistent problem with maintaining their maximum vacuum of 20 inches Hg gage pressure for more than five minutes after the pumps were shut-off. There were many sources for this problem including the solenoids, wiring, fuses, battery, tubing, and the airtight sealant around the tubing and connections. At Pit 3, where the tension sampler investigations were concentrated because this is where the rain simulations began, the 12-amp fuse would always blow out.

After checking the amperage requirements for the pump and solenoids with a voltmeter, the problem was pinpointed to the Level 3 solenoid. It was drawing over 23 amps when it should have only drawn 0.69 amps according to the manufacturers specifications. After the malfunctioning solenoid was replaced, the fuse did not blow out. Additionally, the 10-amp wiring, fuse, and fuse holder were replaced at all five pits with 15-amp wiring, fuses, and fuse holders to provide a greater buffer against equipment that may surge and draw more current than specified and blow out a fuse.

Investigations are continuing into using a pulsing solenoid that requires a brief power pulse to switch it open or closed but does not require power to stay open. Thus, the constant power drain on the batteries is reduced. When the power is shut-off to the solenoids, the solenoid automatically closes. However, it is unknown how to keep track of when the pulsing solenoid is open or closed since there is no default setting. This may possibly interfere with data collection because the solenoid may inadvertently close allowing no water to be collected.

The 675 series marine battery at Pit 3 did not provide sufficient power for prolonged operation of the solenoids and TS pump. With just the pump operating, the battery voltage dropped to 5.4 volts direct current within five minutes; ideally, the battery should remain at 14 volts. With the three solenoids on during pumping, the battery will obviously drain faster. To remedy this, the 675 marine batteries were replaced with fresh batteries. The battery operates most efficiently at 60° - 80°F, but its life will shorten to six months when exposed to temperatures over 100°F. Since the battery was enclosed in a clear lucite container, the temperature could easily have exceeded 100°F on a hot sunny day, thus reducing life expectancy. To prevent overheating in the lucite container, a two-inch ventilation hole was drilled in the upper side of the container and covered with netting to

keep out bugs and debris. The ventilation hole reduced interior temperatures and also dispersed the hydrogen discharge that occurs during battery recharge from the solar panels.

Replacing the solenoid, batteries, and wiring ensured that the pumps would pump at maximum pressure. However, it did little to maintain the TS vacuum once the pump was turned off by the datalogger. At Pits 2 and 4, the vacuum in the tension samplers for all the solenoids would return to atmospheric pressure thirty seconds after the pump was shut-off. At Pit 3, the vacuum held for 25 minutes for Solenoids 1 and 3 and 1.5 minutes for Solenoid 2. The tubing was replaced at Pit 4 but the TS showed no improvement as it lost its vacuum in thirty seconds. To isolate the problem, vacuum tests at Pits 1, 3, and 4 were performed and found that the pumps produced, and indefinitely maintained, 18" Hg pressure between the pumps and the collection bottles. Therefore, the leaks were between the collection bottles and the TSs. Nonetheless, the connections between the collection bottles and the pump were sealed with teflon tape to prevent air leakage.

At Pit 4, the TS tubing had not been placed in conduit to protect it from the environment. Thus, the tubing and connections were weakened, possibly causing air leakage. The above-ground tubing and connections were replaced and inserted in the conduit. The in-line barbs used to connect the tubing were found to be a source of leakage and replaced. The existing tubing was replaced with larger tubing that had an inner diameter equal to the exterior diameter of the TS tubing. The tubing was then "sleeved" together. The individual TSs were isolated for each pit and subjected to a vacuum test to determine the extent and duration of the vacuum after pumping ceased. When problem TSs were found, the tubing and in-line barbs were replaced with the larger tubing and tested again.

Vacuum tests were performed for the TSs for all five pits. This included disconnecting the collection bottles from the TSs and hooking a hand-held vacuum pump to the TS tubing. The pump was turned on until the gage pressure for the TS reached 18" Hg gage. The pump was then turned off and the length of time that it took the TS to reach 2" Hg gage was recorded. For Pits 1, 2, and 3, the gage pressure was recorded if 15 minutes of time elapsed; this was done to conserve time since Pit 5 had TSs that took up to 78 minutes to lose their vacuum. The vacuum test results for the TSs for all five pits are in Table 4.2.8-1.

Table 4.2.8-1 Tension Sampler Vacuum Tests

Pit Number	TS Number	Vacuum Start/End Point (Gage In. of Mercury)	Duration (Minutes, Seconds)
Pit 1	01TS0511	15" → 2"	1 m 23 s
	01TS0512	15" → 2"	1 m 12 s
	01TS0513	15" → 2"	1 m 24 s
Pit 1	01TS0521	15" → 2"	31 s
	01TS0522	15" → 2"	23 s
	01TS0523	15" → 2"	26 s
Pit 1	01TS0531	15" → 2"	48 s
	01TS0532	15" → 2"	51 s
	01TS0533	15" → 2"	51 s
Pit 1	01TS0541	15" → 2"	36 s
	01TS0542	15" → 2"	33 s
	01TS0543	15" → 2"	34 s
Pit 1	01TS0551	15" → 2"	43 s
	01TS0552	15" → 2"	41 s
	01TS0553	15" → 2"	39 s
Pit 1	01TS0561	15" → 2"	28 s
	01TS0562	15" → 2"	31 s
	01TS0563	15" → 2"	33 s
Pit 2	02TSL0511	18" → 2"	12 m 40 s
	02TSL0512	18" → 3.5"	15 m
	02TSL0513	18" → 2"	5 m 34 s
Pit 2	02TSR1011	18" → 2"	7 m 38 s
	02TSR1012	18" → 2"	8 m 50 s
	02TSR1013	18" → 7"	7 m 40 s
Pit 2	02TSL0521	18" → 2"	15 m
	02TSL0522	18" → 2"	8 m 13 s
	02TSL0523	18" → 2"	10 m 5 s
Pit 2	02TSR1021	18" → 2"	9 m 5 s
	02TSR1022	18" → 8.5"	15 m
	02TSR1023	18" → 2"	10 m 20 s
Pit 2	02TSL0531	18" → 17"	15 m
	02TSL0532	18" → 8.5"	15 m
	02TSL0533	18" → 11.5"	15 m
Pit 2	02TSR1031	18" → 2"	4 m 55 s
	02TSR1032	18" → 2"	2 m 7 s
	02TSR1033	18" → 2"	1 m 15 s

Table 4.2.8-1 (cont)

Pit Number	TS Number	Vacuum Start/End Point (Gage In. of Mercury)	Duration (Minutes, Seconds)
Pit 3	03TSR1011	18" → 16.5"	15 m
	03TSR1012	18" → 4.5"	15 m
	03TSR1013	18" → 3"	15 m
Pit 3	03TSL1011	18" → 18"	15 m
	03TSL1012	18" → 17"	15 m
	03TSL1013	18" → 17.5"	15 m
Pit 3	03TSR1021	18" → 2"	3 m 5 s
	03TSR1022	18" → 2"	5 m 37 s
	03TSR1023	18" → 2"	4 m 3 s
Pit 3	03TSL1021	18" → 2"	11 m 47 s
	03TSL1022	18" → 16"	15 m
	03TSL1023	No Data	No Data
Pit 3	03TSR1031	18" → 16"	15 m
	03TSR1032	18" → 2"	1 m 23 S
	03TSR1033	18" → 15"	15 m
Pit 3	03TSL1031	18" → 2"	7 m 48 s
	03TSL1032	18" → 2"	2 m 12 s
	03TSL1033	18" → 2"	13m 50 s
Pit 4	04TS0511	13" → 2"	No Data
	04TS0512	13" → 2"	No Data
	04TS0513	13" → 2"	No Data
Pit 4	04TS1011	13" → 2"	No Data
	04TS1012	18" → 2"	<30 s
	04TS1013	18" → 2"	<30 s
Pit 4	04TS0521	18" → 2"	1 m 40 s
	04TS0522	18" → 2"	4 m 14 s
	04TS0523	18" → 2"	3 m 33 s
Pit 4	04TS1021	18" → 2"	<30s
	04TS1022	18" → 2"	2 m 5 s
	04TS1023	18" → 2"	1 m 38 s
Pit 4	04TS0531	18" → 2"	8 m 50 s
	04TS0532	18" → 2"	7 m 9 s
	04TS0533	18" → 2"	12 m 15 s
Pit 4	04TS1031	18" → 2"	<30 s
	04TS1032	18" → 2"	6 m 3 s
	04TS1033	18" → 2"	3 m 14 s

Table 4.2.8-1 (concl)

Pit Number	TS Number	Vacuum Start/End Point (Gage In. of Mercury)	Duration (Minutes, Seconds)
Pit 5	05TS0511	18" → 2"	9 m 33 s
	05TS0512	18" → 2"	2 m 30 s
	05TS0513	18" → 2"	2 m 20 s
Pit 5	05TS1011	18" → 2"	26 m
	05TS1012	18" → 2"	21 m
	05TS1013	18" → 2"	78 m
Pit 5	05TS0521	18" → 2"	30 m
	05TS0522	18" → 2"	14 m 10 s
	05TS0523	18" → 2"	23 m 50 s
Pit 5	05TS1021	18" → 2"	18 m 30 s
	05TS1022	18" → 2"	16 m 15 s
	05TS1023	18" → 2"	8 m 15 s
Pit 5	05TS0531	18" → 2"	2 m 43 s
	05TS0532	18" → 2"	7 m 4 s
	05TS0533	18" → 2"	2 m 35 s
Pit 5	05TS1031	18" → 2"	18 m
	05TS1032	18" → 2"	11 m
	05TS1033	18" → 2"	10 m
*Gage Pressure Did Not Exceed 13" Hg			

While the results for the TSs were mixed, a remedy to prevent one source of air leakage was to ensure that the bottle caps were tightly replaced. Occasionally, after the water sample was collected by the technician, the cap would not be screwed on tightly causing air to leak through the threads of the bottle. Another possible source of error is that the air leaks occur underground and, therefore, are irreparable. It is also possible that the 20 inch gage pressure created by the pump in the TSs can vaporize the sampling water and allow it to pass through the air portal of the collecting bottle, reducing the volume of water collected. This will be fully investigated during the summer of 1994.

4.3 SOIL MOISTURE

4.3.1 Principles of Time Domain Reflectometry (TDR) Operation

TDR is a relatively new method of determining volumetric soil moisture content. The TDR system used for this application consisted of:

- Cable Tester (Tektronix 1502B)
- 50 Ohm Coaxial Cable (Belden No. 8219)
- 50 Ohm Coaxial Multiplexer (Campbell Scientific SDMX-50)
- Balancing Transformers or Balun (Campbell Scientific)
- Parallel Transmission Cable (RGU58)
- 0.3 cm Diameter Wave Guides (30 cm)

The cable tester incorporated a fast rise voltage pulse generator and an oscilloscope type viewing screen. Signals from the pulse generator propagated without reflection through the hierarchy of coaxial cables and multiplexers to an individual line. The individual line consisted of a coaxial cable running from a multiplexer to a balun. Parallel transmission cable ran from the balun to the waveguides. The balun matched the impedance of the parallel transmission cable to the coaxial cable which reduced any potential reflection. One wave guide was attached to each of the two wires at the end of the parallel transmission cable. The waveguides were placed horizontally into a soil horizon. The signal travelling outward to the waveguides and the reflection from the ends of the waveguides was attenuated according to the materials between the waveguides.

The characteristic that determines the amount of attenuation is referred to as the dielectric constant. If the dielectric constant of the material is high, the signal propagates slower. Typical dielectric constants of air are 1, minerals in soil is 2-3, and water is 80. Considering soil as the surrounding

medium, the dielectric constant of soil water was much higher than its other constituents. A signal within a wet or moist soil propagated slower than in the same soil when dry. (Ionic conductivity affected the amplitude of the signal but not the propagation time). For further discussion see "Phase II RFI/RI Report 903 Pad, Mound and East Trenches Area Operable Unit No. 2, Volume 9, Appendix D, Attachment 5 - Time Domain Reflectometry."

Thus, moisture content was determined by measuring the propagation time over a fixed length probe (i.e., waveguide) embedded in the soil. The clay content in most of the diagnostic horizons of the five soils under study exceeded thirty percent. Thus, attenuation of the signal was too great and no reliable readings of dielectric constant were determined for the soil. To increase the dielectric constant of the media between the waveguides, electrical shrink tubing was placed upon the waveguides. The tubing's dielectric constant increased the overall dielectric constant perceived by the waveguide so that the pulse was not attenuated beyond interpretable levels. Moisture content was determined through different dielectric constants that the probes read in the soil. TDR probe installation information from Pits TR-1 through TR-5 is included in Tables 4.3.1-1 through 4.3.1-5.

4.3.2 TDR Installation and Calibration

Individual TDR probes were verified for accuracy before field installation. Verification was accomplished by relating the TDR/datalogger measured percent water to soil (i.e., by volume), to the percent water to soil (i.e., by volume) calculated by weight measurements using a Mettler brand electronic scale at increasing volumetric moisture content. The accuracy verification of a TDR probe was completed in three steps: (1) the establishment of a control volume, (2) the establishment of a baseline weight of dry soil, and (3) the addition of water to the baseline weight of dry soil and calculation of the volumetric moisture content. The procedure used, as well as the analytical results, are included in Appendix V. Due to the repetitious nature of the probe, accuracy verification results are contained in the *TDRCAL* Directory on the SSG_SNBK Bernoulli data diskette. See Appendix XI, 'TDR Calibration Data Location' for details.

Designation	Tension Samplers		TDR Probes				
	Depth ¹ (cm)	Distance ² (cm)	Designation	Probe Length (cm)	Depth ¹ (cm)	Distance ² (cm)	Covered (Yes/No)
01TS051			01TDR111	30	13	150	Yes
01TS0511	17	143	01TDR112	30	21	150	Yes
01TS0512	17	157	01TDR113	30	28	143	Yes
01TS0513	28	150	01TDR114	30	28	157	Yes
01TS101			01TDR121	30	12	455	Yes
01TS1011	16	448	01TDR122	30	20	455	Yes
01TS1012	16	462	01TDR123	30	27	448	Yes
01TS1013	27	455	01TDR124	30	27	462	Yes
01TS052			01TDR211	30	40	95	Yes
01TS0521	44	88	01TDR212	30	48	95	Yes
01TS0522	44	102	01TDR213	30	55	88	Yes
01TS0523	55	95	01TDR214	30	55	102	Yes
01TS102			01TDR221	30	41	315	Yes
01TS1021	45	308	01TDR222	30	49	315	Yes
01TS1022	45	322	01TDR223	30	56	308	Yes
01TS1023	56	315	01TDR224	30	56	322	Yes
01TS053			01TDR311	30	67	208	Yes
01TS0531	71	201	01TDR312	30	75	208	Yes
01TS0532	71	215	01TDR313	30	82	201	Yes
01TS0533	82	208	01TDR314	30	82	215	Yes
01TS103		380	01TDR321	30	66	380	Yes
01TS1031	70	373	01TDR322	30	74	380	Yes
01TS1032	70	387	01TDR323	30	81	373	Yes
01TS1033	81	380	01TDR324	30	81	387	

Legend:

- 1 Depths were measured from the distance below a cloth measuring tape stretched across the trench face.
- 2 Distances were measured from a fixed stake at the far left side of trench.

Trench TR-2							
Designation	Tension Samplers		TDR Probes				
	Depth ¹ (cm)	Distance ² (cm)	Designation	Probe Length (cm)	Depth ¹ (cm)	Distance ² (cm)	Covered (Yes/No)
02TS051			02TDR111	30	7.6	35.6	No
02TS0511	12.7	25.4	02TDR112	30	16.5	35.6	No
02TS0512	14.0	40.6	02TDR113	30	20.3	30.5	No
02TS0513	22.9	35.6	02TDR114	30	22.9	43.2	No
02TS101			02TDR121	30	10.2	119.4	No
02TS1011	10.2	106.7	02TDR122	30	20.3	121.9	No
02TS1012	12.7	124.5	02TDR123	30	20.3	109.2	No
02TS1013	25.4	111.8	02TDR124	30	27.9	121.9	No
02TS052			02TDR211	30	25.4	91.4	No
02TS0521	35.6	83.8	02TDR212	30	35.6	94.0	No
02TS0522	35.6	96.5	02TDR213	30	45.7	76.2	No
02TS0523	48.3	83.8	02TDR214	30	43.2	99.1	No
02TS102			02TDR221	30	25.4	264.2	No
02TS1021	33.0	254.0	02TDR222	30	35.6	264.2	No
02TS1022	38.1	269.2	02TDR223	30	40.6	254.0	No
02TS1023	43.2	264.2	02TDR224	30	43.2	271.8	No
02TS053			02TDR311	30	76.2	203.2	No
02TS0531	83.8	200.7	02TDR312	30	86.4	205.7	No
02TS0532	86.4	221.0	02TDR313	30	91.4	198.1	No
02TS0533	91.4	203.2	02TDR314	30	86.4	221.0	No
02TS103			02TDR321	30	91.4	370.9	No
02TS1031	101.6	360.7	02TDR322	30	101.6	370.8	No
02TS1032	104.1	375.9	02TDR323	30	111.8	358.1	No
02TS1033	111.8	363.2	02TDR324	30	111.8	375.9	No

2 Distances were measured from a fixed stake at the far left side of trench.

Trench TR-3							
Designation	Tension Samplers		TDR Probes				
	Depth ¹ (cm)	Distance ² (cm)	Designation	Probe Length (cm)	Depth ¹ (cm)	Distance ² (cm)	Covered (Yes/No)
03TS101			03TDR111	30	12.7	20.3	Yes
03TS1011	22.9	10.2	03TDR112	30	25.4	21.6	Yes
03TS1012	19.1	22.9	03TDR113	30	30.5	17.8	Yes
03TS1013	30.5	20.3	03TDR114	30	31.8	27.9	Yes
03TS101			03TDR121	30	2.5	396.2	Yes
03TS1011	10.2	388.6	03TDR122	30	11.4	396.2	Yes
03TS1012	11.4	406.4	03TDR123	30	19.1	391.2	Yes
03TS1013	17.8	398.8	03TDR124	30	14.5	403.9	Yes
03TS102			03TDR211	30	16.5	221.0	Yes
03TS1021	22.9	210.8	03TDR212	30	29.2	221.0	Yes
03TS1022	22.9	226.10	03TDR213	30	40.6	213.4	Yes
03TS1023	40.6	221.0	03TDR214	30	38.1	226.1	Yes
03TS102			03TDR221	30	26.7	378.5	Yes
03TS1021	33.0	368.3	03TDR222	30	36.8	378.5	Yes
03TS1022	33.0	386.10	03TDR223	30	48.3	365.8	Yes
03TS1023	45.7	378.5	03TDR224	30	47.0	381.0	Yes
03TS103			03TDR311	30	66.0	149.9	Yes
03TS1031	66.0	142.2	03TDR312	30	68.6	154.9	Yes
03TS1032	66.0	160.0	03TDR313	30	81.3	147.3	Yes
03TS1033	73.7	154.9	03TDR314	30	83.8	157.5	Yes
03TS103			03TDR321	30	63.5	226.1	Yes
03TS1031	68.6	210.8	03TDR322	30	78.7	221.0	Yes
03TS1032	69.9	233.7	03TDR323	30	88.9	219.7	Yes
03TS1033	88.9	226.1	03TDR324	30	92.7	231.1	

- 1 Depths were measured from the distance below a cloth measuring tape stretched across the trench face.
- 2 Distances were measured from a fixed stake at the far left side of trench.

Trench TR-4							
Designation	Tension Samplers		TDR Probes				
	Depth ¹ (cm)	Distance ² (cm)	Designation	Probe Length (cm)	Depth ¹ (cm)	Distance ² (cm)	Covered (Yes/No)
04TS051			04TDR111	30	7.6	81.3	No
04TS0511	15.2	76.2	04TDR112	30	40.6	81.3	No
04TS0512	12.7	88.9	04TDR113	30	20.3	76.2	No
04TS0513	27.9	86.4	04TDR114	30	20.3	88.9	No
04TS101			04TDR121	30	7.6	518.2	No
04TS1011	15.2	510.5	04TDR122	30	17.8	513.1	No
04TS1012	12.7	528.3	04TDR123	30	27.9	515.6	No
04TS1013	27.9	513.1	04TDR124	30	27.9	525.8	No
04TS052			04TDR211	30	35.6	322.6	Yes
04TS0521	33.0	312.4	04TDR212	30	40.6	312.4	Yes
04TS0522	37.9	320.0	04TDR213	30	40.6	330.2	Yes
04TS0523	43.2	322.6	04TDR214	30	50.8	322.6	Yes
04TS102			04TDR221	30	33.0	416.6	Yes
04TS1021	33.0	401.3	04TDR222	30	38.1	419.1	Yes
04TS1022	33.0	419.1	04TDR223	30	40.6	403.9	Yes
04TS1023	45.7	411.5	04TDR224	30	43.2	421.6	Yes
04TS053			04TDR311	30	66.0	241.3	Yes
04TS0531	71.1	233.7	04TDR312	30	71.1	231.1	Yes
04TS0532	66.0	246.4	04TDR313	30	94.0	228.6	Yes
04TS0533	78.7	241.3	04TDR314	30	94.0	243.8	Yes
04TS103			04TDR321	30	66.0	330.2	Yes
04TS1031	73.7	312.4	04TDR322	30	76.2	327.7	Yes
04TS1032	76.2	335.3	04TDR323	30	78.7	320.0	Yes
04TS1033	78.7	327.7	04TDR324	30	78.7	332.7	

2 Distances were measured from a fixed stake at the far left side of trench.

Designation	Tension Samplers		TDR Probes				
	Depth ¹ (cm)	Distance ² (cm)	Designation	Probe Length (cm)	Depth ¹ (cm)	Distance ² (cm)	Covered (Yes/No)
05TS051			05TDR111	20	20	3	No
05TS0511	14	3	05TDR112	20	18	10	No
05TS0512	13	13	05TDR113	20	18	20	No
05TS0513	18	30	05TDR114	20	25	28	No
05TS101			05TDR121	15	23	308	No
05TS1011	23	298	05TDR122	15	30	301	No
05TS1012	23	318	05TDR123	15	30	315	No
05TS1013	34	307	05TDR124	15	39	308	No
05TS052			05TDR211	30	23	393	Yes
05TS0521	24	400	05TDR212	30	23	407	Yes
05TS0522	38	392	05TDR213	30	30	400	Yes
05TS0523	38	408	05TDR214	30	46	400	Yes
05TS102			05TDR221	30	28	466	Yes
05TS1021	28	473	05TDR222	30	28	479	Yes
05TS1022	41	463	05TDR223	30	35	473	Yes
05TS1023	41	480	05TDR224	30	46	473	Yes
05TS053			05TDR311	30	56	127	Yes
05TS0531	61	119	05TDR312	30	65	127	Yes
05TS0532	61	135	05TDR313	30	79	120	Yes
05TS0533	73	127	05TDR314	30	79	134	Yes
05TS103			05TDR321	30	56	334	Yes
05TS1031	61	326	05TDR322	30	65	334	Yes
05TS1032	61	342	05TDR323	30	79	327	Yes
05TS1033	73	334	05TDR324	30	79	341	

Legend:

- 1 Depths were measured from the distance below a cloth measuring tape stretched across the trench face.
- 2 Distances were measured from a fixed stake at the far left side of trench.

4.3.3 TDR Data

The TDR soil moisture data is in the form of percent volumetric soil moisture. The Campbell Scientific Inc. (CSI) datalogger used the Ledieu (1986) algorithm to interpret waveforms from the cable tester into a value of soil matrix dielectric constant and then into volumetric soil moisture content.

The CSI datalogger executed every 1.5 hours. Each probe required 45 to 90 seconds to evaluate. The 1.5 hour interval was the shortest regular interval, for a 24-hour cycle, which could be performed. The data collected was of the highest temporal resolution possible for the configuration used.

The TDR soil moisture data is contained in the *Soil* Directory on the SSG_SNBK Bernoulli data diskette. See Appendix XI, 'TDR Soil Moisture Data Location' for details.

4.3.4 TDR Problems and Solutions

It was necessary to modify the TDR system to obtain results at RFETS. Soil composition consisted of a significantly high proportion of clay. The dense clay material apparently was able to deplete the signal to the point at which no rebound was created in the waveform and, therefore, the waveform was not interpretable. By insulating the probes, the necessary rebound was obtained. Analysis of data collected indicated that there was no significant loss in sensitivity of the probes which were insulated as opposed to standard probes.

The TDR system was periodically plagued by what appeared to be diurnal effects. For several periods, the TDR data collected during the night would consist entirely of out-of-range values. The issue is still being investigated. The legitimate values collected during the daytime seemed to be unaffected and produced output which appeared to be valid.

4.4 MATRIC POTENTIAL

4.4.1 Principles of Tensiometer Operation

Tensiometers operate by allowing water within the tensiometer to equilibrate with water in the soil through a porous ceramic cup (See Fig. 4.4.1-1). A tensiometer consists of the ceramic cup, a tube that connects the cup to the ground surface, and a cap that seals the top of the tube.

The forces of matric potential provide a suction that draws water from the interior of the tensiometer until an equivalent vacuum is created within the tensiometer. Matric potential (or “tensiometer pressure potential,” Jury, et al., 1991) is a component of water potential. It is related to the adsorptive forces of the soil matrix and is formally defined as the energy per unit volume required to transfer reversibly and isothermally an infinitesimal amount of solution containing solutes from a reservoir of solution at reference pressure and elevation (i.e., the water table) to the point of interest in the soil (Jury, et al. 1991).

Water potential is formally defined as the amount of work that a unit quantity of water in an equilibrium soil-water system is capable of doing when it moves to a pool of water in the reference state at the same temperature (Hanks and Ashcroft, 1980). The water table is usually chosen as the reference state. At points above the water table, this quantity has a negative value (i.e., vacuum). The negative pressure of the tensiometer solution is proportional to the matric potential. This vacuum varies with changes in soil water content. The vacuum may be measured by a pressure transducer, mechanical vacuum gauge, or manometer ported to the interior of the tensiometer. It may be converted into units (i.e., Pascals, bars, psi, and atmospheres) that are commonly used to characterize the energy state of groundwater.

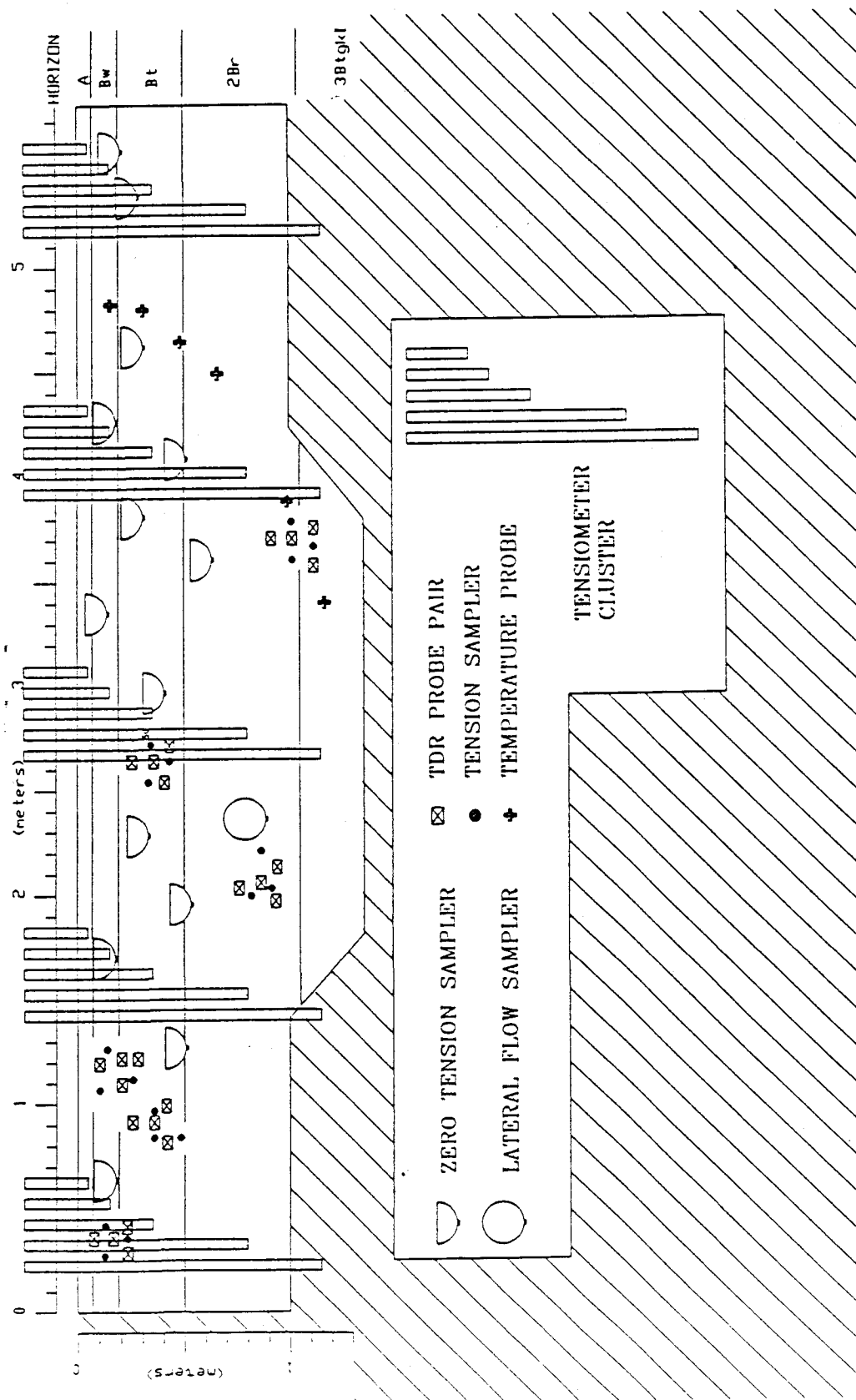


Figure 4.4.1-1 Pit face map showing locations of tensionmeters relative to pit instruments. Tensionmeter locations are projected into the plane of view. Locations are approximate and for illustrative purposes only.

4.4.2 Tensiometer Installation

A total of 119 tensiometers were installed in the field immediately adjacent to and upslope from the pits. They were arranged in clusters of five (some variation occurs between pits) so that each cluster was located opposite a tension infiltrometer measuring station (See Fig. 4.4.1-1). In each cluster, a tensiometer monitored matric potential in each of the five soil horizons that were tested by the infiltrometer. The matric potential data was used in conjunction with the hydraulic conductivities obtained from adjacent infiltrometer experiments to calculate unsaturated hydraulic conductivity and other parameters.

Tensiometer installation followed guidelines described in the RFETS Operable Unit (OU2) SOP GT.27, "Field Use of Tensiometers" included in Appendix VII. Tensiometers were installed into holes in undisturbed soils that were hand augured to a the depth of a targeted soil horizon.

Tensiometers were inserted into the augured holes so that the ceramic cup was in direct contact with the surrounding soil. Because the interaction of vegetation with soil affected matric potential, care was taken to prevent damage to surrounding plants and to the soil column. All installation operations were conducted from a scaffold 0.5 m wide by 6 m long elevated 15 cm above the ground surface.

The specific depths for the installation of tensiometers were determined in one of two ways.

- 1) If the pit had already been excavated, the PI chose the depths based on observations of the soil profile exposed in the pit.
- 2) At sites where the pit had not yet been excavated, exploratory holes were dug with a screw or bucket auger to elucidate the soil profile.

Spoils were collected at 5 cm depth increments and laid out in a column to illustrate the stratigraphy. Depths were then chosen to gain matric potential data from the different soil horizons that appeared in the hole.

A variety of methods were required to install the tensiometers in the soils of the study area. Several types of hand augers were useful in creating holes for tensiometers. These included bucket and screw augers, sampling tubes, and core tubes. Bucket augers were most useful in loose (i.e., noncohesive) soils. Screw augers only worked well in soils that contained small (< 2 cm diam.) rocks and muddy soils. Sampling and core tubes were driven to the desired depth when dense, rocky soil was encountered.

Bucket and screw augers created a hole that was larger than the outer diameter of the tensiometer. In these cases, the spoils from the hole were made into a slurry and poured back in around the tensiometer to seat it in place. In stratified soil columns, the spoils were separated by horizon and the tensiometer was installed. The soil column about the tensiometer was recreated by successively placing slurries of corresponding soil types down the hole. Due to the initial dry soil conditions, water from slurries temporarily reduced the matric potential of the surrounding soil, thus the collection of useful matric potential data was delayed for several weeks. Matric potential data collected during the first two weeks after installation followed a drying curve representing dispersal of water emplaced during installation.

Sampling tubes or lengths of steel pipe sharpened at one end worked well for tensiometer installation in most soils. Their outer diameter was chosen to be as close as possible to that of the tensiometer. A slide hammer or post-driver was used to insert the tubes into the ground. Because these tubes created a hole which fit tightly around the tensiometer, a slurry was not required. Deionized water was poured down into the hole, which eased tensiometer insertion and also improved contact between the soil and the ceramic cup. This type of installation was found to be less destructive to the soil and surrounding foliage than other methods used.

When auguring through the surficial dry, silty loam, the augured hole tended to cave-in. A bucket auger with a small aperture was often necessary to retain soil that was withdrawn from the hole. To increase the cohesiveness of the soil and allow it to be removed, water was poured into the hole. Water also helped stabilize the walls of the hole. Thus, cave-ins were prevented.

Rocks in the soils encountered at Pits 2 through 5 complicated tensiometer installation. The screw and bucket augers occasionally pushed rocks out of the way. However, they were often unable to

proceed, which forced abandonment of the hole. Rocks that protruded into the holes also cracked the ceramic cup of several tensiometers during insertion.

The core tube, used almost exclusively at Pit 4, was capable of passing through the 20-30 cm thick rocky layer that occurred in varied intensities at all tensiometer locations. Rapid progress of the auger was permitted below the rocky layer because the soil was generally clayey and moist. At Pit 5 the rocks encountered in the soils of the second horizon were too numerous. Thus, hand auguring was not permitted. An electric rock drill also attempted, but failed, to auger holes through the rocky horizon. To facilitate tensiometer installation, nine tensiometers were placed in excavations made previously during infiltrometer testing which were dug below the rocky horizon.

Tensiometer installation data for Pits 1 through 5 are included in Tables 4.4.2-1 through 4.4.2-5. Tensiometers of five overall lengths, 41-, 71-, 102-, 132-, and 161 cm were installed at the five pit sites. At Pit 1 the five soil horizons identified, A, AB, Bt, Btk, and Btgk, were monitored at depths of 10-, 20-, 35-, 50-, and 70 cm, respectively. The tensiometers were arranged in five clusters of five to seven tensiometers each except Pit 5 where three clusters of three tensiometers were installed. The clusters were placed approximately opposite and across the pit from the infiltrometer test sites. The clusters were evenly spaced and spanned the 5 to 6 m length of the pits.

4.4.3 Tensiometer Data

Tensiometer data was measured and recorded using a Tensicorder. A Tensicorder is a portable datalogger connected to a pressure transducer. Pressure (i.e., vacuum) was measured through a hollow needle attached to the transducer which penetrated the septum cap of the tensiometer. The actual water tension in the soil around the porous cup was the value on the data logger read-out (mbar x 1.02 cm water/mbar) minus the length (cm) of the water column in the tensiometer. Data collection procedures using a Tensicorder and resulting matric potential calculations are explained in SOP GT.27.

The sampling of Tensiometers followed guidelines set forth in EMD SOP GT.31, "Field Use of Tensiometers."

Tensiometer field data are included on the SSG_SNBK Bernoulli data diskette in the *TENSIO* Directory. See Appendix XI, 'Tensiometer Matric Potential Data Location' for details.

Table 4.4.2-1 Trench TR-1 Tensiometers

Trench TR-1 Tensiometers				
Designation	Length	Cup Depth ¹ (cm)	Location (x)	Location (y)
01TS11	41	11.5	149.86	83.82
01TS12	71	20.02	137.16	83.82
01TS13	102	35.7	119.38	86.36
01TS14	132	54.98	142.24	99.06
01TS15	161	77.06	119.38	109.22
01TS21	41	16.44	246.38	78.74
01TS22	71	22.12	233.68	78.74
01TS23	102	40.9	220.98	78.74
01TS24	132	52.78	243.84	99.06
01TS25	161	69.16	226.06	104.14
01TS31	41	19.54	358.14	93.98
01TS32	71	36.42	345.44	88.9
01TS33	102	36.5	342.9	109.22
01TS34	132	55.88	325.12	111.76
01TS35	161	67.86	314.96	81.28
01TS41	41	13.84	449.58	78.74
01TS42	71	23.72	439.42	71.12
01TS43	102	39.3	426.72	71.12
01TS44	132	56.18	416.56	78.74
01TS45	161	71.46	426.72	93.98
01TS51	41	9.24	556.26	109.22
01TS52	71	20.12	523.24	91.44
01TS53	102	26.2	535.94	101.6
01TS54	132	56.18	508	91.44
01TS55	161	73.46	515.62	109.22
Legend:				
1 Below ground surface at location of each tensiometer.				

Table 4.4.2-2 Trench TR-2 Tensiometers

Trench TR-2 Tensiometers				
Designation	Length	Cup Depth (cm)	Location (x)	Location (y)
02TS11	41	16.64	134.62	129.54
02TS12	71	25.12	124.46	119.38
02TS13	102	34.6	109.22	119.38
02TS14	132	62.38	116.84	129.54
02TS15	132	78.88	137.16	119.38
02TS21	41	16.94	205.74	129.54
02TS22	71	25.12	193.04	114.3
02TS23	102	38.6	226.06	132.08
02TS24	132	58.58	231.14	124.46
02TS25	132	71.88	210.82	116.84
02TS31	41	15.24	279.4	152.4
02TS32	71	17.92	269.24	142.24
02TS33	102	45.8	292.1	157.48
02TS34	132	59.28	281.94	129.54
02TS35	132	65.88	297.18	142.24
02TS41	41	14.74	373.38	147.32
02TS42	71	23.32	370.84	129.54
02TS43	102	43.9	360.68	149.86
02TS44	132	56.78	345.44	139.7
02TS45	132	63.38	360.68	139.7
02TS51	41	18.64	439.42	162.56
02TS52	71	24.62	452.12	162.56
02TS53	102	45.3	462.28	149.86
02TS54	132	53.08	444.5	152.4
02TS55	132	69.88	429.26	149.86
Legend:				
1 Below ground surface at location of each tensiometer.				

Table 4.4.2-3 Trench TR-3 Tensiometers

Trench TR-3 Tensiometers				
Designation	Length	Cup Depth ¹ (cm)	Location (x)	Location (y)
03TS11	41	18.6	76.2	223.52
03TS12	41	23.5	76.2	233.68
03TS13	71	36	60.96	233.68
03TS14	102	44.2	96.52	220.98
03TS15	102	56.5	96.52	233.68
03TS16	132	70	111.76	215.9
03TS17	132	82.4	106.68	231.14
03TS21	41	14	180.34	233.68
03TS22	41	23.3	167.64	243.84
03TS23	71	34.4	182.88	246.38
03TS24	102	41.8	187.96	236.22
03TS25	102	53.8	154.94	236.22
03TS26	132	73	205.74	228.6
03TS27	132	82	205.74	241.3
03TS31	41	13.3	231.14	220.98
03TS32	41	14.1	246.38	246.38
03TS33	71	32.2	269.24	220.98
03TS34	102	43.3	271.78	233.68
03TS35	102	52.0	254	243.84
03TS36	132	69.0	243.84	220.98
03TS37	132	84.9	254	228.6
03TS41	41	14.3	365.76	220.98
03TS42	41	24.7	340.36	223.52
03TS43	71	34.2	353.06	238.76
03TS44	102	43.8	327.66	236.22
03TS45	102	58.9	363.22	238.76
03TS46	132	64.4	337.82	241.3
03TS47	132	85	317.5	238.76
03TS51	41	13.2	416.56	198.12
03TS52	41	23.8	424.18	190.5
03TS53	71	36.8	388.62	218.44
03TS54	102	42.8	447.04	208.28
03TS55	102	55.7	464.82	200.66
03TS56	132	68.1	467.36	218.44
03TS57	132	79.1	439.42	218.44

Legend:

¹ Below ground surface at location of each tensiometer.

Table 4.4.2-4 Trench TR-4 Tensiometers

Trench TR-4 Tensiometers				
Designation	Length	Cup Depth ¹ (cm)	Location (x)	Location (y)
04TS11	41	15	142.24	154.94
04TS12	71	31.6	149.86	152.4
04TS13	71	43.6	137.16	170.18
04TS14	102	59.1	175.26	170.18
04TS15	102	70.3	162.56	154.94
04TS21	41	11.6	233.68	167.64
04TS22	71	25.1	228.6	157.48
04TS23	102	62.7	243.84	152.4
04TS24	102	65.8	220.98	175.26
04TS25	102	69.3	213.36	157.48
04TS31	41	14	322.58	172.72
04TS32	71	28.9	317.5	147.32
04TS33	102	66.3	330.2	160.02
04TS34	71	34.8	294.64	172.72
04TS35	102	75.2	307.34	160.02
04TS41	41	13.4	408.94	149.86
04TS42	71	42.2	403.86	162.56
04TS43	71	45.6	396.24	149.86
04TS44	102	57.6	383.54	157.48
04TS45	102	66.6	391.16	165.1
04TS51	41	14.7	464.82	162.56
04TS52	71	26.9	482.6	157.48
04TS53	71	43.1	472.44	154.94
04TS54	102	69.8	485.14	157.48
04TS55	102	64.1	487.68	147.32
Legend:				
1 Below ground surface at location of each tensiometer.				

Table 4.4.2-5 Trench TR-4 Tensiometers

Trench TR-4 Tensiometers				
Designation	Length	Cup Depth ¹ (cm)	Location (x)	Location (y)
04TS11	41	15	142.24	154.94
04TS12	71	31.6	149.86	152.4
04TS13	71	43.6	137.16	170.18
04TS14	102	59.1	175.26	170.18
04TS15	102	70.3	162.56	154.94
04TS21	41	11.6	233.68	167.64
04TS22	71	25.1	228.6	157.48
04TS23	102	62.7	243.84	152.4
04TS24	102	65.8	220.98	175.26
04TS25	102	69.3	213.36	157.48
04TS31	41	14	322.58	172.72
04TS32	71	28.9	317.5	147.32
04TS33	102	66.3	330.2	160.02
04TS34	71	34.8	294.64	172.72
04TS35	102	75.2	307.34	160.02
04TS41	41	13.4	408.94	149.86
04TS42	71	42.2	403.86	162.56
04TS43	71	45.6	396.24	149.86
04TS44	102	57.6	383.54	157.48
04TS45	102	66.6	391.16	165.1
04TS51	41	14.7	464.82	162.56
04TS52	71	26.9	482.6	157.48
04TS53	71	43.1	472.44	154.94
04TS54	102	69.8	485.14	157.48
04TS55	102	64.1	487.68	147.32

Legend:

1 Below ground surface at location of each tensiometer.

4.4.4 Tensiometer Problems and Solutions

Problems encountered during installation of tensiometers were discussed in Section 4.4.2.

The Tensicorder data storage protocol could not distinguish a measurement of zero pressure and a non-measurement. Thus, all data storage locations containing zeros in the Tensicorder were skipped when the data was downloaded. This shortcoming caused problems because some storage locations were skipped when the tensiometer to be measured was broken. Broken tensiometers could not be easily distinguished from those which were measuring saturated conditions. The data had to be examined manually and updated with zeros in the appropriate conditions. This flaw will disappear when pressure transducers are permanently dedicated to each tensiometer.

Environment conditions can adversely affect tensiometer performance and damage tensiometers. Freezing weather can cause the tensiometer to freeze, destroying its ceramic cup. As a remedy, antifreeze shall be placed in the tensiometers. Experiments are being conducted to produce calibration algorithms for different antifreezes in tensiometers. Once completed, these experiments shall be detailed in future revisions of this notebook. Occasionally, deer kick tensiometer shafts, breaking them. This problem is considered inconsequential and has not been addressed. Diurnal temperature variations may cause spurious trends in tensiometer output. Experimental designs to confront this problem are being evaluated. The experiments and their results shall be detailed in future revisions of this document once they are completed.

4.5 HYDRAULIC CONDUCTIVITY

4.5.1 Principles of Tension Infiltrometer Operation

Tension infiltrometers were used to estimate unsaturated hydraulic conductivity in Pits 1 through 5. The two infiltrometers used were supplied by Soil Measurement Systems in Tucson, Arizona. One device (Unit No. 1) had a baseplate diameter (effective) of 8.4 cm and the other (Unit No. 2) was modified to accommodate a baseplate diameter of 22.6 cm. The larger base infiltrometer was predominately used throughout the testing except during the final pit (4) where both devices were used concurrently. Infiltrations were conducted at five near-equal spaced locations along the length

of the pit at the same soil horizons as the placement of interstitial soil solution samplers and tensiometers (See Tables 4.5.1-1 through 4.5.1-5). Testing was conducted along the pit wall opposite the installed soil solution sampling apparatus. At each of the 85 locations tested, steady-state (i.e., unconfined) infiltrations were measured at four tensions: 0-, 3-, 6-, and 15 cm water tension.

Table 4.5.1-1 Trench TR-1 Infiltrometer Test Locations

Trench TR-1 Infiltrometer Test Locations				
Test Number	Horizon	Depth ¹ (cm)	Distance ² (cm)	Lotus 1-2-3 Filename
1	A	0	10.2	X1_01.WK1
2	A	0	91.4	X1_02.WK1
3	A	0	228.6	X1_03.WK1
4	A	0	350.2	X1_04.WK1
5	A	0	447.0	X1_05.WK1
6	A	0	538.5	X1_06.WK1
7	Btk	40	40.6	X1_07.WK1
8	Btk	35	182.9	X1_08.WK1
9	Btk	38	406.4	X1_09.WK1
10	Btk	38	495.3	X1_10.WK1
11	Btg	45	152.4	X1_11.WK1
12	Btg	44	243.8	X1_12.WK1
13	Btg	50	495.3	X1_13.WK1
14	Btg	46	538.5	X1_14.WK1

Legend:

- 1 Depths were measured from the distance below a cloth measuring tape stretched across the trench face.
- 2 Distances were measured from a fixed stake at the far left side of trench.

Table 4.5.1-2 Trench TR-2 Infiltrrometer Test Locations

Trench TR-2 Infiltrrometer Test Locations				
Test Number	Horizon	Depth ¹ (cm)	Distance ² (cm)	Lotus 1-2-3 Filename
1	A	0	30	X2_01.WK1
2	A	0	130	X2_02.WK1
3	A	0	250	X2_03.WK1
4	A	0	400	X2_04.WK1
5	A	0	550	X2_05.WK1
6	Bw	15	50	X2_06.WK1
7	Bw	20	130	X2_07.WK1
8	Bt	30	230	X2_08.WK1
9	Bt	35	390	X2_09.WK1
10	Bt	30	540	X2_10.WK1
11	2Br	45	60	X2_11.WK1
12	2Br	45	120	X2_12.WK1
13	2Br	45	225	X2_13.WK1
14	2Br/2Btgkl	65	375	X2_14.WK1
15	2Br	55	550	X2_15.WK1

Legend:

1 Depths were measured from the distance below a cloth measuring tape stretched across the trench face.

2 Distances were measured from a fixed stake at the far left side of trench.

Table 4.5.1-3 Trench TR-3 Infiltrrometer Test Locations

Trench TR-3 Infiltrrometer Test Locations				
Test Number	Horizon	Depth ¹ (cm)	Distance ² (cm)	Lotus 1-2-3 Filename
1	A	0	60	X3_01.WK1
2	A	0	170	X3_02.WK1
3	A	0	300	X3_03.WK1
4	A	0	400	X3_04.WK1
5	A	0	460	X3_05.WK1
6	AB	10	75	X3_06.WK1
7	Bw	25	160	X3_07.WK1
8	Bw	30	260	X3_08.WK1
9	Bw	30	370	X3_09.WK1
10	Bw	30	470	X3_10.WK1
11	Btg	30	100	X3_11.WK1
12	Btg	40	160	X3_12.WK1
13	Btg	45	270	X3_13.WK1
14	Btg	50	375	X3_14.WK1
15	Btg	45	475	X3_15.WK1

Legend:

1 Depths were measured from the distance below a cloth measuring tape stretched across the trench face.

2 Distances were measured from a fixed stake at the far left side of trench.

Table 4.5.1-4 Trench TR-4 Infiltrrometer Test Locations

Trench TR-4 Infiltrrometer Test Locations					
Test Number	Unit ¹	Horizon	Depth ¹ (cm)	Distance ² (cm)	Lotus 1-2-3 Filename
1	2	A	0	0	X4_01.WK1
2	1	A	0	30	X4_02.WK1
3	2	A	0	125	X4_03.WK1
4	1	A	0	155	X4_04.WK1
5	2	A	0	250	X4_05.WK1
6	1	A	0	275	X4_06.WK1
7	2	A	0	340	X4_07.WK1
8	1	A	0	370	X4_08.WK1
9	2	A	0	475	X4_09.WK1
10	1	A	0	490	X4_10.WK1
11	2	Bt1	20	0	X4_11.WK1
12	1	Bt1	20	20	X4_12.WK1
13	2	Bt1	15	100	X4_13.WK1
14	1	Bt1	15	130	X4_14.WK1
15	2	Bt1	15	260	X4_15.WK1
16	1	Bt1	15	295	X4_16.WK1
17	2	Bt1	15	360	X4_17.WK1
18	1	Bt1	15	395	X4_18.WK1
19	2	Bt1	15	475	X4_19.WK1
20	1	Bt1	15	285	X4_20.WK1
21	2	Bt2	35	25	X4_21.WK1
22	1	Bt2	35	0	X4_22.WK1
23	2	Bt2	35	115	X4_23.WK1
24	1	Bt2	35	145	X4_24.WK1
25	2	Bt2	35	265	X4_25.WK1
26	1	Bt2	35	290	X4_26.WK1
27	2	Bt2	35	350	X4_27.WK1
28	1	Bt2	35	380	X4_28.WK1
29	1	Bt2	35	445	X4_29.WK1
30	2	Bt2	35	475	X4_30.WK1

Legend:

- 1 Depths were measured from the distance below a cloth measuring tape stretched across the trench face.
- 2 Distances were measured from a fixed stake at the far left side of trench.

Table 4.5.1-5 Trench TR-5 Infiltrometer Test Locations

Trench TR-5 Infiltrometer Test Locations				
Test Number	Horizon	Depth ¹ (cm)	Distance ² (cm)	Lotus 1-2-3 Filename
1	A	0	30	X5_01.WK1
2	A	0	90	X5_02.WK1
3	A	0	250	X5_03.WK1
4	A	0	350	X5_04.WK1
5	A	0	475	X5_05.WK1
6	Btg	20	50	X5_06.WK1
7	Btg	50	125	X5_07.WK1
8	Btg	40	250	X5_08.WK1
9	Btg	35	350	X5_09.WK1
10	Bw	20	490	X5_10.WK1
11	Btg	45	470	X5_11.WK1

Legend:

1 Depths were measured from the distance below a cloth measuring tape stretched across the trench face.

2 Distances were measured from a fixed stake at the far left side of trench.

A schematic diagram of a tension infiltrometer is shown in Figure 4.5.1-1. The major components are the bubbling tube, water reservoir, and porous baseplate. The bubbling (i.e., tension control) tube had three air entry ports that controlled applied surface tension by allowing air entry at four different depths below the water column surface. The ports were preset and calibrated to tensions (i.e., negative pressure) from 0 (low) to 15 cm (high), with pinch clamps used to switch from one tension to another. The ZT was attained by raising the 3 cm air entry tube to a calibrated level below the water column surface. The infiltrometers were constructed of clear acrylic. The diameter of the bubbling and water reservoir tubes were 2.54 cm I.D. A replaceable porous nylon membrane covered the porous baseplate. A single pressure transducer port was located at the top of the water reservoir tube. Infiltrometers were recalibrated following the installation of replacement membranes.

Infiltration testing was conducted following the RFETS OU2 SOP GT.26; "Determining Hydraulic Conductivity Using a Tension Infiltrometer" which is located in Appendix VIII. After the pit was excavated by the backhoe at each infiltration site, an area was dug to the required depth with a rock hammer and shovel. Depth measurements were taken from the opposite pit wall with a carpenter level and tape measure. Distance measurements were taken from the left edge of the pit wall containing the sampling apparatus (See Tables 4.5.1-1 through 4.5.1-5). At each test location an

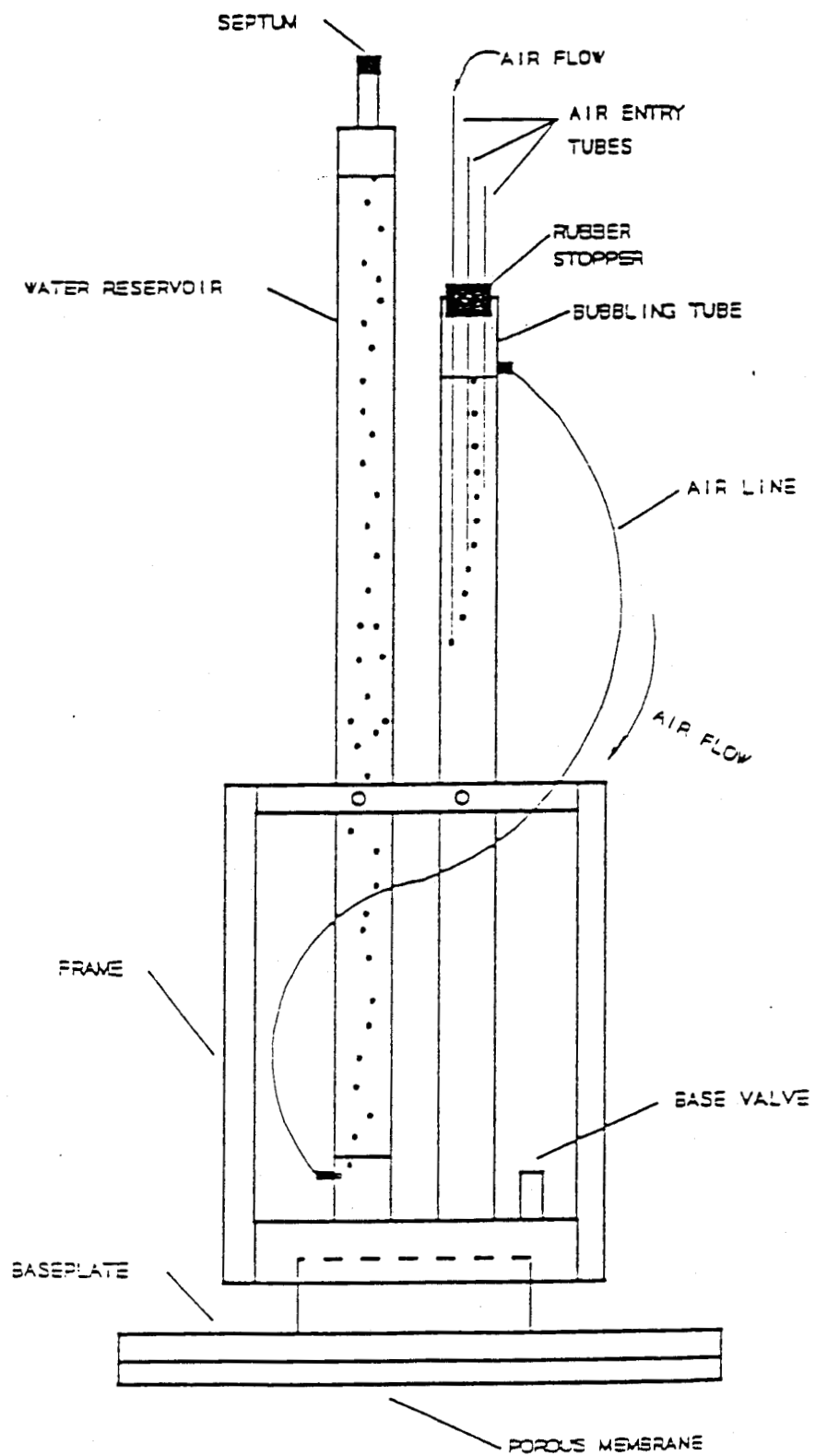


Figure 4.5.1-1 Tension Infiltrometer

area approximately 40 cm square was cleared and leveled using a masonry trowel. Slight compaction of the first horizon was noted at all five pits due to the backhoe and project personnel that worked around the pit. Minimal smearing was noted at all horizons due to the initial dry conditions. At the first horizon, plant roots were trimmed at the soil surface using a swiss army knife or scissors.

Flow measurements were taken from low to high tension (0 to 15 cm). An insertion ring, 2.5 cm x 28.3 cm O.D., was used to delimit the surface infiltration area for the larger infiltrometer at Pits 1 and 5. A surficial ring 20 cm I.D. was used during testing at Pits 2, 3, and 4. A smaller diameter insertion ring, 1.5 cm x 8.4 cm O.D., was used for all infiltration testing with the smaller infiltrometer. The large and small insertion rings were pushed 1.5 cm and 0.5 cm into the soil, respectively. Two layers of cheesecloth were placed onto the soil surface that minimized slaking of silica sand into the soil macropores and to protected the porous nylon mesh from being punctured by plant roots. To ensure better contact with the infiltrometer base, clean silica sand was placed into the insertion or surficial ring, leveled approximately 2 mm above the ring, and the infiltrometer placed upon the sand.

With the infiltrometer water reservoir filled and applied surface tension preset at 0, one or more water reservoir volumes, 500 ml to 2000 ml, were placed into the soil column. The prewetting of the soil was conducted before infiltration measurements, this allowed a steady state rate to be obtained quickly in the dry soil. A single pressure transducer connected to a portable data logger (Tensicorder; Soil Measurement Systems) was used to monitor infiltration flux. A unit change in the height of the water column was linearly related to the unit change in tension (1.02 cm of water is equal to .1 kPa pressure). When the saturated ($h=0$) measurements were completed, the infiltrometer was removed from the ring and the water reservoir refilled.

The silica sand within the ring was releveled and the infiltrometer placed back upon the sand. The large diameter infiltrometer needed no anchoring to prevent rocking by wind gusts. However, the smaller unit was stabilized by the insertion of four sharpened metal rods through holes at the corners of the base. When the surface tension preset was at 3 cm, unsaturated infiltration was conducted. The Tensicorder was started after the water entrapped in the air entry tube was evacuated and air bubbled through to the water reservoir tube. Bubbling indicated that the desired tension at the soil surface had been attained. When possible, this procedure was repeated for the 6

cm and 15 cm tensions, but not all tensions were conducted at each location. It was noted that increased applied surface tension decreased the infiltration rate.

4.5.2 Tension Infiltrometer Data

Raw data from the hydraulic conductivity tests are included on the SSG_SNBK Bernoulli data diskette in the *INFILTRO* Directory. See Appendix XI, 'Tension Infiltrometer Data Location' for details. Spatial variability of hydraulic conductivity in the vadose zone is in the "Phase II RFI/RI Report 903 Pad, Mound and East Trenches Area Operable Unit No. 2, Volume 9, Appendix D, Attachment 8."

4.6 WATER TABLE

4.6.1 Principles of Piezometer Operation

Piezometers were used to measure the depth of the water table from the ground surface. A small hole was drilled from the ground surface to below the groundwater table and a pipe was inserted in the hole. The base of the pipe was screened to allow the groundwater level to freely change in the pipe. The upper-end of the pipe was capped to keep out obstructions.

The distance to the water table was measured with a manometer, a hand held instrument consisting of a pressure sensing instrument and a long slender tube extending from it. To find the groundwater depth, the manometer was turned on to establish the baseline pressure by exposing the open end of the tube to the atmosphere. The open-end of the tube was slowly inserted into the piezometer pipe until the pressure reading from the manometer showed a constant increase above the baseline reading; this indicated that the tube had penetrated the groundwater surface. The tube was marked at the ground surface and pulled out of the piezometer pipe. The distance from the ground surface mark to the open-end of the tube was measured with a tape measure to determine the distance from the ground surface to the groundwater table to within one inch.

4.6.2 Piezometer Installation

Piezometers were installed at each pit to allow monitoring of the depth of local groundwater. Piezometer installation was performed by personnel from GEO Environmental Services; Golden, Colorado. The piezometers were installed using an expandable stainless steel pipe. The pipe was threaded at each end to allow a total well depth up to 915 cm. An expendable well point was located at the tip of the first section of pipe. Before installation, well materials were decontaminated and rinsed using deionized water. Equipment rinsate samples were not taken. Using a hydraulic ram attached to a four-wheel all-terrain vehicle (ATV) (Scorpion), the technician installed the piping to the depth specified by the PI. The area around the pipe at the ground surface was sealed using bentonite grout. Piezometer data showing the piezometer name, location, state coordinates, piezometer status, soil type, surface elevation, top of casing elevation, distance to the bottom of the piezometer, total depth of piezometer casing, and depth of bedrock are listed in Table 4.6.2-1. GEO Environmental Services documents are included in Appendix IX.

Table 4.6.2-1 Piezometer Data

RF Well Name	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5
Location	N8	N8	N8	N8	N8
State North	748858.08	748893.74	748905.14	748874.02	748914.31
State East	2086844.2	2086744.2	2086691.4	2086632.3	2086562.0
Piezometer Status	Installed	Installed	Installed	Installed	Intalled
Soil Type	Alluvium	Alluvium	Alluvium	Alluvium	Alluvium
Surface Elev (ft)	5917.03	5924.91	5929.95	5932.12	5944.89
Top of Casing (ft)	5917.03	5924.91	5929.95	5932.12	5944.89
Bottom of Scrn (ft)	10	15	18	18	18
Casing Depth (ft)	10	15	18	18	18
Top of Bedrock	Not Det	Not Det	Not Det	Not Det	Not Det

4.6.3 Piezometer Data

Piezometer data was recorded weekly and before and after the rain simulations during the summer of 1993. The data is stored in the SS4 OU2 Field Log Book titled "OU2 Surficial Soil Project 5/23/92-" located onsite.

Electronic versions of piezometer data are included on the SSG_SNBK in the PIEZO Directory. See Appendix XI, 'Piezometer Data Location' for details.

4.6.4 Piezometer Problems and Solutions

The piezometer only provided data accurate to 2.5 cm due to the fact that it was measured by hand and that the tubing did not remain completely linear when it was pushed into the piezometer pipe. At Pit 5, a small pebble had fallen into the piezometer pipe, thus, blocking the manometer tube from entering. This prevented data from being collected for this pit for several weeks in the summer of 1993. Inconsistencies would arise when different technicians would measure the groundwater depth. Some technicians would stretch the manometer tubing more than others when the outstretched tubing was measured with the measuring tape.

To solve these problems, 20 new automated piezometers will be installed throughout the site and linked into the Campbell Scientific data retrieval system. Not only will this keep all measurements consistent, but it will also allow for frequent data collection that may be crucial for groundwater modeling.

4.7 SOIL TEMPERATURE

4.7.1 Principles of Temperature Probe Operation

The Campbell Scientific 107 Temperature Probe uses the Fenwal Electronics UUt51J1 Thermistor. This thermistor is a nonmetallic solid. Its electrical resistance changes with temperature. Campbell Scientific datalogger Instruction 11 is used to measure the 107 Temperature Probe. This instruction sends a precise excitation voltage of 2V AC to the probe, makes a single-ended voltage

measurements, then converts the output to Celsius with a fifth order polynomial. Details of this output conversion can be found in 'Model 107 Temperature Probe Instruction Manual.'

4.7.2 Soil Temperature Probe Installation and Calibration

Campbell Scientific Model 107B Temperature Probes were installed into the wall of each pit. The data obtained was used to monitor soil temperature versus depth and to determine thermal gradient over time for each pit. The temperature probes were installed into holes created by driving a steel spike 15 cm long into the pit wall. The spike, followed by the soil, was removed from the hole, mixed into a slurry, and then placed around the installed probe. The temperature probe cable was protected using 1.9 cm I.D. flexible conduit. The temperature probes were connected through an AM416 Multiplexer to the CR-10 datalogger. Temperature probe installation locations are listed in Table 4.7.2-1 and shown in Figures 4.1.4-1 through 4.1.4-6.

4.7.3 Soil Temperature Probe Data

Soil temperature probe measurements are included in the dataset collected with the TDR measurements. These datafiles are named with the date retrieved with the extension *.TDR. For example, data uploaded from the field on February 1, 1994 would be named 020194.TDR. These files are archived in the raw data and database formats on the Terra personal computer and on Bernoulli diskette at the Soils Laboratory at RFETS. Another backup is stored on the Land personal computer at in Building 080, Interlocken. In addition, the files are periodically archived by the Rocky Flats Environmental Database System (RFEDS).

The soil temperature data, contained in the TDR dataset, is included on the SSG_SNBK Bernoulli data diskette in the Soil Directory. See Appendix XI, 'Soil Temperature Data Location' for details.

4.7.4 Soil Temperature Probe Problems and Solutions

There were no problems with the 107 Soil Temperature Probes. Temperature probe output reflected the insulating character of soil, showing an increased dampening of diurnal atmospheric temperature effects with depth.

Table 4.7.2-1 Temperature Probes

Temperature Probes		
Designation	Location	
	Depth ¹ (cm)	Distance ² (cm)
Trench TR-1		
01TP01	13	194
01TP02	27	201
01TP03	66	162
Trench TR-2		
02TP01	15.2	428.6
02TP02	30.5	480.1
02TP03	48.3	464.8
02TP04	66.0	449.6
02TP05	99.1	388.6
02TP06	116.8	340.4
Trench TR-3		
03TP01	0	302.3
03TP02	22.9	299.7
03TP03	43.2	304.8
03TP04	88.9	304.8
Trench TR-4		
04TP01	63.5	396.2
04TP02	53.3	335.3
04TP03	30.5	353.1
04TP04	45.7	233.7
04TP05	61.0	193.0
04TP06	12.7	238.8
04TP07	15.2	381.0
04TP08	91.4	177.8
Trench TR-5		
05TP01	12	368
05TP02	34	356
05TP03	76	370

Legend:

- 1 Depths were measured from the distance below a cloth measuring tape stretched across the trench face.
- 2 Distances were measured from a fixed stake at the far left side of trench.

4.8 PRECIPITATION

4.8.1 Principles of Rain Gauge Operation

Rain data was collected in the field by a Texas Electronics TE525 Tipping Bucket Rain Gauge which was a smaller adaptation of the standard Weather Bureau Tipping Bucket Rain Gauge. The TE525 measured rainfall at rates up to 2 inches per hour with an accuracy of $\pm 1\%$. The rain gauge funneled rain into a bucket mechanism that tipped when filled to a calibrated level of .01 inch. A magnet attached to the tipping mechanism actuated a momentary switch closure as the bucket tipped. The switch closure was recorded by a pulse counter and sent to a datalogger.

The aluminum sensor housing of the rain gauge was coated with a white, baked enamel surface to withstand exposure to the environment. A debris filter was placed above the funnel orifice to keep insects and debris out of the tipping mechanism.

4.8.2 Rain Gauge Installation and Calibration

The TE525 Tipping Bucket Rain Gauge was set up in the field according to Texas Electronic specifications. It was wind-protected by an Alter-Type Wind Screen and was attached 75 cm above the ground to a five cm outer-diameter metal pipe. The rain gauge was connected to the CR-10 datalogger by 18 meters of 2-conductor cable. Field calibration of the rain gauge was done annually according to Texas Electronic specifications.

4.8.3 Rain Gauge Data

Rain data was recorded every five minutes by the datalogger. However, to prevent an overflow of data in the storage module, the rain data was only stored when a rain event has occurred. When a rain event occurred, the data was stored in an array that was marked with the number 005 for identification and the time and amount of precipitation collected in the five minute period.

Rain data is included on the SSG_SNBK Bernoulli data diskette in the *SOIL* Directory. See Appendix XI, 'Rain Gauge Data Location' for details.

4.8.4 Rain Gauge Problems and Solutions

The rain gauge had no serious problems outside of regular maintenance. Approximately two or three times a year, debris was removed from the filters, funnel orifices, and bucket reservoirs as necessary to ensure accurate data collection.

4.9 RAIN SIMULATION

4.9.1 Rain Simulation Operations

An automated spraying system was constructed to conduct rainfall simulation experiments over the five test pits during June and July of 1993. The apparatus was comprised of two main systems: (1) a delivery system and (2) an application system. Figures 4.9.1-1 through 4.9.1-5 show the rain simulator frame and application system.

4.9.1.1 Delivery System—The delivery system consists of the following components:

- 1,135 Liter Water Reservoir
- 9.14 m Head Sump Pump (Teal 4.5 Amp/110 Volt)
- 91.5 liters/min (lpm) Centrifugal Pump (*Black and Decker* 5 Amp/110 Volt)
- 0 to 1724 kPa Pressure Regulator (*Spraying Systems* Model No. 11438-250)
- 0 to 690 kPa Pressure Gauge (*Spraying Systems* Model No. 11438-73)
- Analog Input Flow Indicator (*Omega* Model No. DPF402)
- Paddle Wheel Flow Sensor (*Omega* FTB603)
- 10 m of Reinforced Nylon Tubing

4.9.1.2 Delivery System Set Up and Operation—The sump pump was used to prime the centrifugal pump with water obtained from the 1,135 liter reservoir. The reservoir was filled each morning with water obtained from the fire hydrant located in the conex. The centrifugal pump supplied the water to the spray header at constant rate and pressure. A pressure regulator was used to apply the desired amount of water to the ground surface. A flow sensor and flow monitor were used to monitor the rates of application. A flow meter displayed the rates and recorded the total

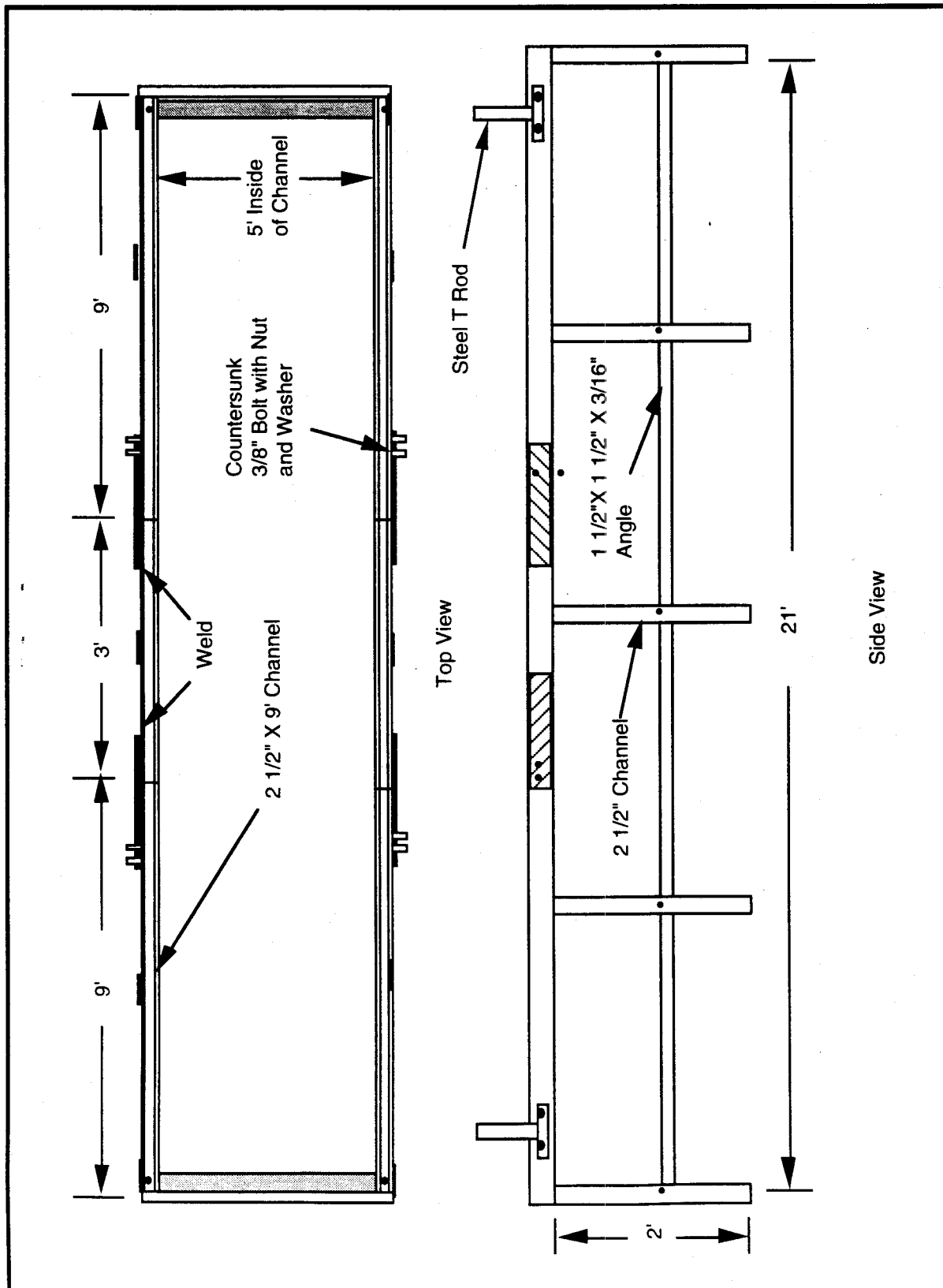


Figure 4.9.1-1 Rain Simulator Frame

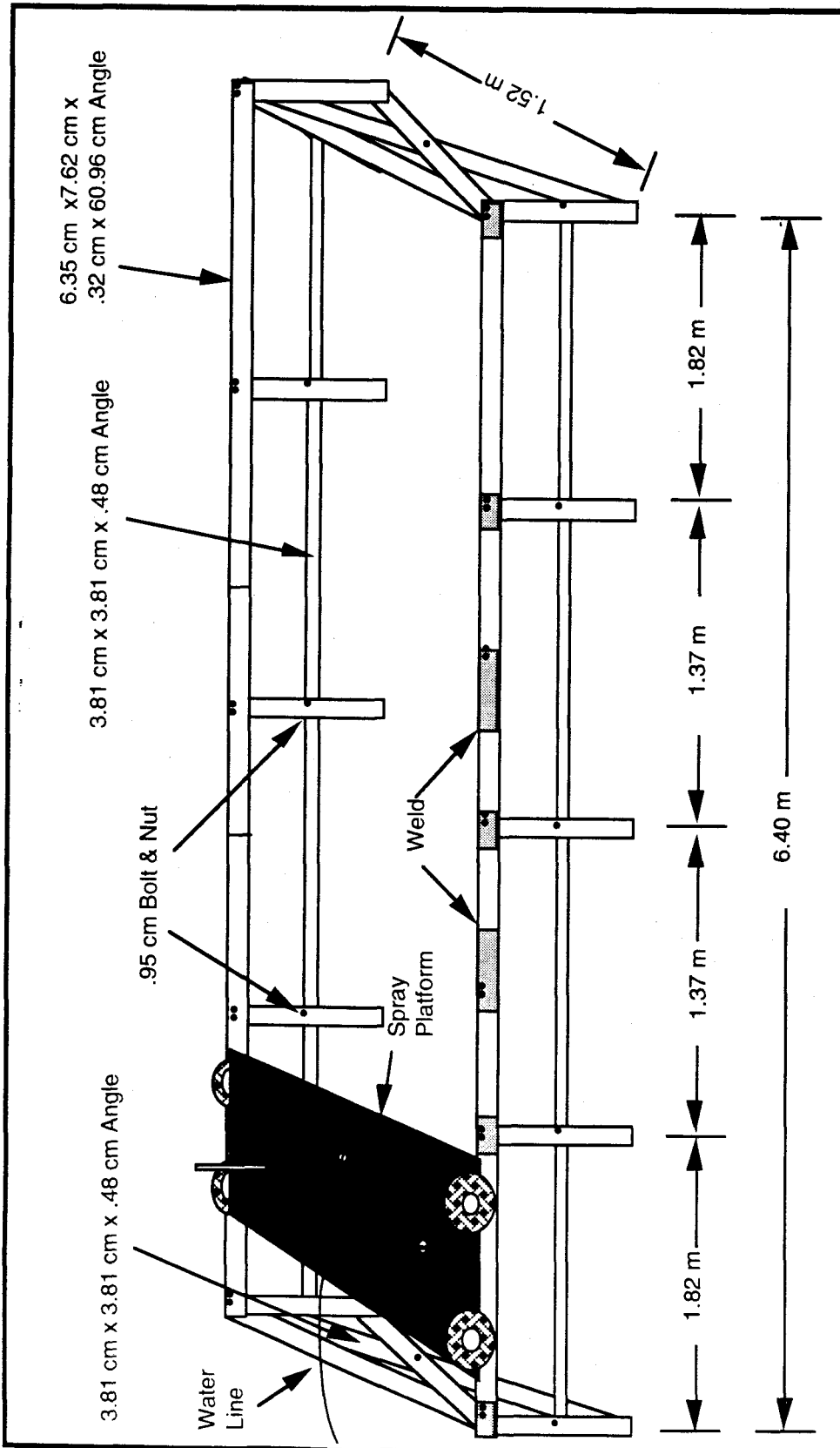


Figure 4.9.1-2 Rain Simulator Frame- Sideview

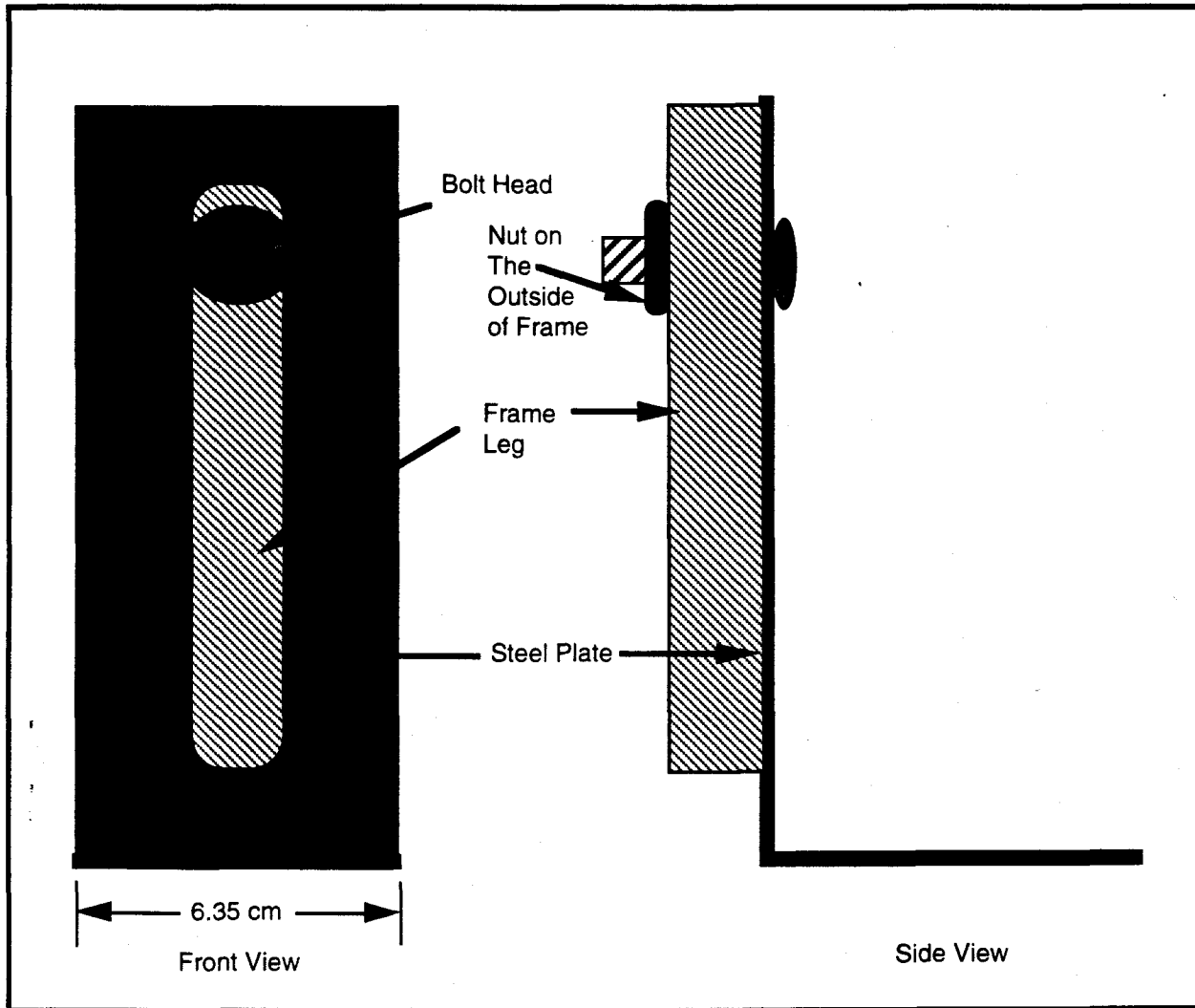


Figure 4.9.1-3 Rain Simulator Frame – Adjustable Leg Detail

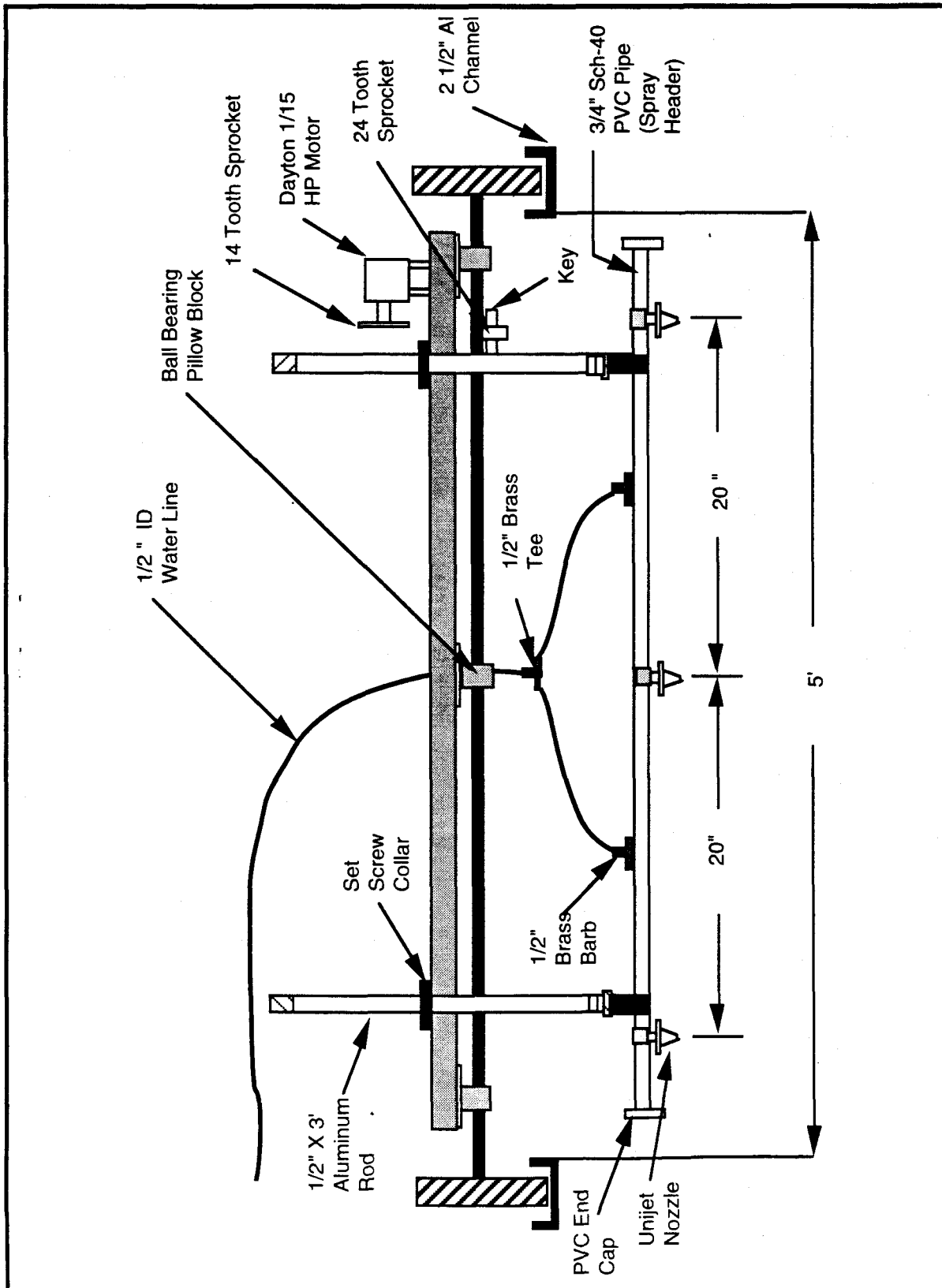


Figure 4.9.1-4 Rain Simulator Frame – Spray System End View

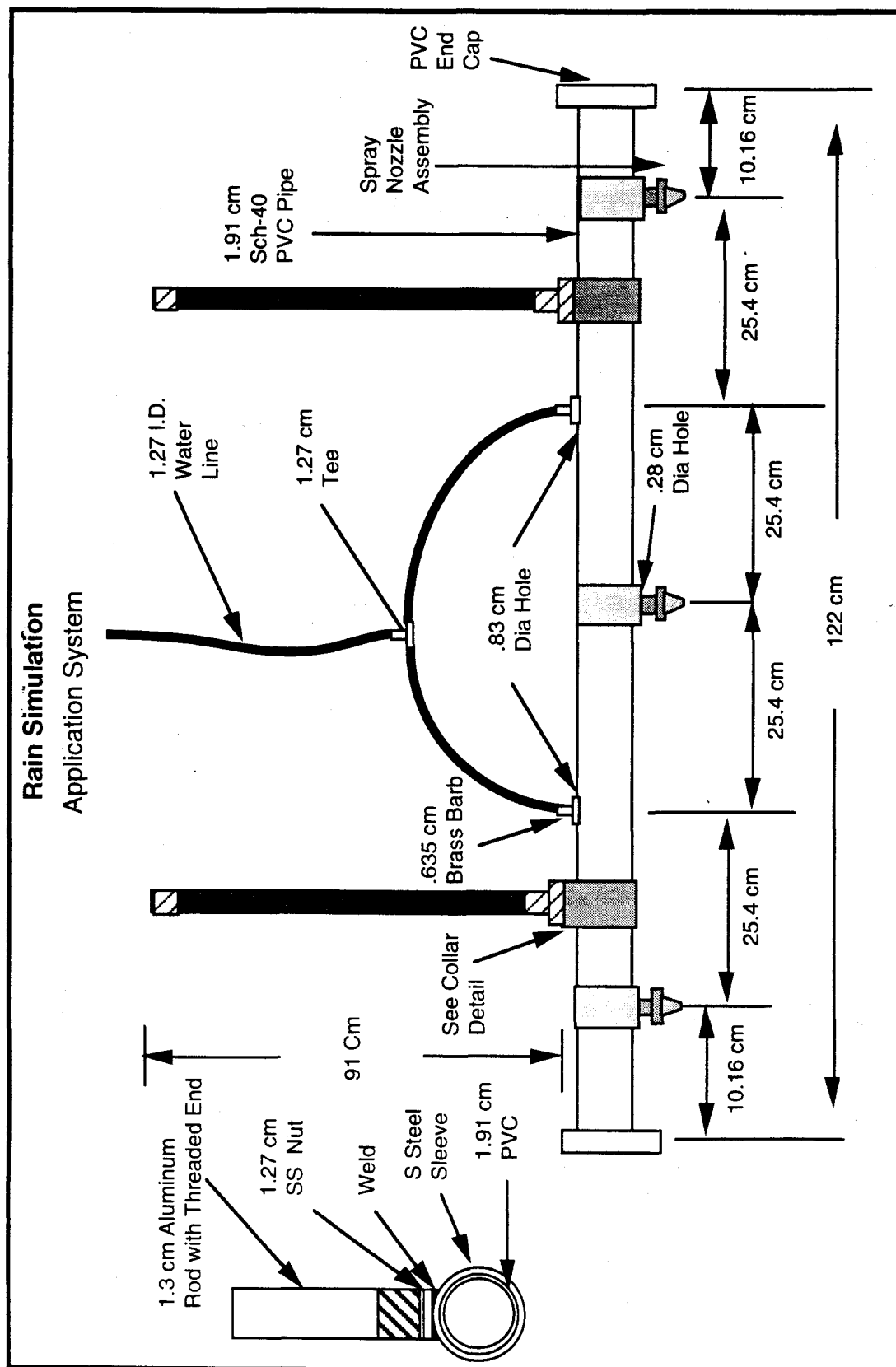


Figure 4.9.1-5 Rain Simulation Application System – Spraying System

volume of water applied to the plot. An in-line stop-cock was used to stop the flow when the volume applied reached a targeted amount.

4.9.1.3 Application System—The application system consisted of three main components:

- 1) A Motorized Spray Platform
- 2) A Three Nozzle Adjustable Height Sprayer
- 3) A Lightweight Aluminum Support Frame

The spray platform consisted of a plywood sheet with steering and drive axles to which four wheels were attached. A 50 Watt/110 voltage alternating current (VAC) motor with reduction gearing and rheostat speed control drove the platform along the top of the aluminum support frame. The direction of the platform was automatically reversed when the double-pole, double-throw switch on the motor contacted one of the two steel "T-rods" located at each end of the simulator. See Figures 4.9.1-1 through 4.9.1-3 for more details.

The spray header consisted of PVC pipe (1.91 cm in diameter) with caps glued to both ends. Three *Unijet* flat spray nozzles were equally spaced along the 48 cm length of the PVC pipe. Two aluminum rods, extending up from the PVC pipe through the spray platform, were positioned to achieve uniform spray application. The rods were secured by metal collars. See Figures 4.9.1-4 and 4.9.1-5 for more details.

The tips of the *Unijet* nozzles were interchangeable to allow for the application of flow rates varying from 5.87 to 9.54 L/m. Seven sets of the *Unijet* nozzles were used to attain the design flow rates. (See Table 4.9.1.3-1).

The spray platform traveled along the top of the lightweight aluminum support frame. The top of the frame was made of aluminum C-channels, which provided a track for the wheels of the spray platform. Ten adjustable legs, five to each side, were likewise constructed of aluminum C-channels. Each leg was able to vary .2 m, increasing the frame's stability on the terrain.

Table 4.9.1.3-1 Nozzle Specifications

Tip Number	Rated Flow at 34.5 kPa	Rated Flow at 3447.5 kPa	Design Flow	Pressure (kPa)	Height (cm)
TP8006SS	0.795	7.95	1.08	172.38	44.8
TP8008SS	1.06	10.6	1.61	231.67	46.60
TP73094SS	1.25	12.5	1.96	251.67	53.30
TP8010SS	1.32	13.2	2.81	275.80	45.70
TP8015SS	2.00	20.0	3.18	256.49	43.20
TP8020SS	2.69	26.9	4.54	291.66	45.08
TP8030SS	4.16	40.12	5.03	117.22	52.70
Source: Industrial Spray Products Catalog 51 Produced by Spraying Systems Co.					

The integrity of the spray application was maintained by a wind skirt and by the length of the frame. The wind skirt (i.e., thick plastic sheeting) was attached to the sides of the frame with 2.54 cm of velcro stripping. The wind skirt reduced the deformation of the spray pattern caused wind interference. The frame was built to allow for 30.5 cm of overhang. This additional length allowed for the full development of the spraying pattern before the platform reached the test plot, thus reducing boundary effects.

4.9.1.4 Precipitation Monitoring Equipment—Three TE525 Texas Instruments Tipping Bucket Rain Gauges recorded the precipitation at the test plots. The information yielded by the rain gauges was used to determine if the application was uniform over the plot for the duration of the simulation. One rain gauge was placed in the center of the plot wetted by the simulator, while the other two rain gauges were placed at each end of the plot.

The rain gauges were connected to an SDM-SW8A multiplexer, and wired to a CR-10 datalogger. The datalogger recorded the Julian day, hour-minute, battery voltage, and the precipitation received by each of the rain gauges during five minute intervals. Data from the datalogger was automatically transferred to an SM716 Storage Module. The SM716 was removed from the field and downloaded daily. The CR-10, SDM-SW8A, and the SM716 were all powered by an 18 Watt CSI Solar Panel.

4.9.1.5 Performance Testing and Preparation for Field Experiments—Nineteen graduated cylinders beneath the simulator, flush to the bottom of the frame, were used to test the

uniformity of the application. The volume of the water collected by each cylinder was monitored during the simulation and the total volume was recorded at the end of the simulation. The simulator was adjusted until the tests showed that the variability along the length and width of the frame was less than 10 percent.

4.9.1.6 Rain Simulations—Rain simulation experiments were performed from June 28 to July 30 of 1993. During this time, 23 simulations were completed. Simulation variables included duration, intensity, and frequency.

The rain simulator was designed to simulate storms of 10, 25, 50, and 100-year return periods. A return period being defined as the average recurrence interval between events equaling or exceeding a specified magnitude. Events, with these return periods were selected to provide a range of rain events that may yield a flow of water through the soil environment. A 100-year event was selected to represent the practical upper limit of the hydrologic design scale.

The rain simulator was constructed to apply water at a constant rate making it impractical to emulate the actual fluctuation in intensities that occur during a natural event. Therefore, an average flow rate was applied to the plot during the experiments.

4.9.1.7 Precipitation Calculations—The intensities, durations, and frequencies of 2, 5, 10, 25, 50, and 100-year return events were calculated using guidelines and historical data contained in *The Precipitation Frequency Atlas of the Western United States*. The atlas supplied information for storms of six and 24-hour durations. The procedure outlined below describes the method used to obtain 3, 2, .5, and .25 hour estimates for storms of these return periods.

The Colorado isopluvial maps located in the Atlas displayed the depth of rain values for 2, 5, 10, 25, 50, and 100-year return periods. The following equation was used to determine the precipitation depth for 2 and 100-year events for a one hour duration.

where:

$Y(2)$ = depth of rain for a 2-year return event with a duration of one hour;

x(1) = rain depth for a 2-year return period with a duration of 24-hours;

x(2) = rain depth for a 2-year return period with a duration six hour duration;

Y(100) = depth of rain obtained from a 100-year event with one hour duration;

x(3) = rain depth for 100-year event 24-hour duration;

x(4) = rain depth obtained form a 100-year event with a 24-hour duration.

z = elevation of site in hundreds of feet relative to sea level

Values for return periods other than 2 or 100-years with a sixty minute duration, were linearly interpolated with the following equation:

where:

P(yr) = rain depth for return period with duration used for P2yr and P100yr;

a = see Table 4.9.1.7-1;

b = see Table 4.9.1.7-1;

P2yr = rain depth for 2 year return event with one hour duration; and

P100yr = rain depth for 100-year return event with one hour duration.

Table 4.9.1.7-1 Coefficients Used in Eq(3)

Return Period	a	b
5	0.674	0.278
10	0.496	0.449
25	0.293	0.669
50	0.146	0.835

Source: Chow 1988.

The following equation was used to determine the precipitation-frequency values for the 2, 5, 10, 25, 50, and 100-year return periods with durations of 30, 15, 10, and 5 minutes.

where:

a = coefficient obtained from Table 4.9.1.7-2

P1yr = return period being analyzed with a one hour duration

Table 4.9.1.7-2 contains the values used to obtain 5, 10, 15, and 30 minute estimations from one hour values.

Table 4.9.1.7-2 Contains the values used to obtain 5, 10, 15, and 30 minute estimations from one hour values.

Time (Minutes)	Ratio to one Hour (a)
5	0.29
10	0.45
15	0.57
30	0.79

Source: U.S. Weather Bureau Technical Paper No. 40, 1961.

Intensities of rain events of less than one hour were calculated following a procedure highlighted in *The Precipitation Frequency Atlas of the Western United States*. The volume of water needed to simulate the design events over the plots was calculated by taking the product of the depth of precipitation required for the event by the surface area covered by the simulator. The following equation was used:

where:

I = Intensity (cm/hr);

A = Area wetted by the simulator(cm²);

D = density of water (liter/cm²);

T = duration of event.

The flow rate necessary to apply the correct volume of water during the allotted time was calculated using the following calculation:

where:

N= the number of nozzles over the area

The frequencies, durations, and intensities yielded by these calculations are summarized in Appendix X.

4.9.1.8 Field Experiments—The daily tasks performed before, during, and after the rain simulations were:

- 1,135 liter water tank filled with hydrant water.
- The nozzles were changed on the spray platform as required by the design intensity.
- The nozzle height was adjusted to ensure a uniform spraying pattern.
- The rain gauges were placed beneath the rain simulator.
- The storage module was connected to the datalogger, and the electronic equipment was tested.
- The rain simulation was performed at the design intensity and duration.
- The plot was covered with plastic sheeting reduce evaporation effects.

4.9.2 Rain Simulation Problems and Solutions

Some unanticipated events were encountered during the testing and conduction of the rain simulations, calling for changes in the equipment and experiment design. These modifications assisted in improving the integrity of the simulations.

The pump selected to supply the water from the reservoir to the spray header was unable to deliver water at the rate and pressure needed to produce a uniform spraying pattern. A Unijet pump, rated at 50 liters per minute (lpm), was originally used to supply the water to the spray header. During laboratory testing of the simulator, it was found that the pump was unable to supply water at the design rate. A 91.5 lpm Black and Decker pump was substituted for the Unijet pump. The Black

and Decker centrifugal pump was coupled with a 9.14 m head sump pump which was used to supply the water to the pump from the reservoir. This system was used throughout simulations and was able to provide the spray header with the rates and pressures required to simulate events ranging from 10 to 100 years. The Black and Decker pump sustained considerable wear due to the back pressure exerted by the nozzles. An industrial strength pump might be better suited for this application in the future.

The tygon tubing selected to carry the water from the reservoir to the simulator was not capable of sustaining the pressure exerted by the system and was replaced with reinforced tygon tubing. The tubing was used to carry water to the pump and then to the spray header of the simulator. The pressure that the tubing was subjected to was much higher than anticipated, causing the tubing to swell. Reinforced tubing, with the same inner diameter as the tygon tubing, replaced and functioned well under the pressures of the system for the remainder of the simulations.

The electrical demand of the modifications made to the simulator built in 1992 required a more powerful generator. The 110 Volt AC/5000 Watt portable generator used in 1992 was unable to sustain the load created by the two pumps, flow meter, and motor. Therefore, a larger portable generator, more capable of handling the increased demand, was used.

The aluminum frame was not wide enough to wet the entire area from the zero TSs to the tensiometers. Two of the trenches required two simulations to cover the full area. The rain simulator used during the summer of 1993 should be widened by approximately 20 cm to allow for full coverage of the area. The frame was lengthen by 30 cm which allowed for full coverage of all the trenches lengthwise, but additional length would assist in further reduction of boundary effects.

The rain gauges were placed on the ground surface instead of being secured to the frame as was initially designed. The original design was to secure the rain gauges to the sides of the aluminum frame. However, during the laboratory testing of the rain simulator the rain gauges produced inconsistent data thought to be a result of boundary effects, runoff from the frame, and the close proximity of the top of the gauge to the nozzles. The rain gauges were placed on the ground surface 12 cm from the frame to reduce the error due to the aforementioned factors. However, error was entered into the data yielded by the gauges due to the unevenness of the ground surface.

The design of the simulator makes it very difficult to use standard tipping bucket rain gauges to obtain accurate estimates to the amount of rain applied to the plot.

Finally, the trenches were modified to assist in the simulations. The data collected from the tensiometers and the ZT samplers after the first simulation, a 10-year event, showed that very little of the applied water had reached the ground surface. Therefore, the vegetation was clipped to approximately 5 to 10 cm above the ground surface. The vegetation of the trenches was thick. Before clipping, a few of the plants extended above the height of the simulator itself. The clipping of the vegetation allowed for more of the applied water to reach the ground surface as was shown by comparison of the data yielded from the tensiometers and ZT samplers before and after the modification.

4.10 SNOW MELT MONITORING COMPONENT

4.10.1 Snow Melt Modelling

A snow melt study is being conducted to examine its potential role in the transport of actinides. Field data suggests that snow melt may cause the most intensive flushing of water through the soil column. In addition, rain-on-snow events RFETS are common and represent the most extreme snow melt rate potential.

Snow melt modelling will be done with an energy and mass balance approach. The snow system will be divided into three components: (1) the underlying soil, (2) the snowpack itself, and (3) the atmosphere. Energy exchange will be modelled at the soil/snow and snow/atmosphere interfaces.

SNTHERM.89 (US CRREL) will be used as the modelling software. SNTHERM.89 is a process driven, one-dimensional mass and energy balance model. The model predicts snowpack temperature profiles based on initial snowpack temperatures and meteorological data. By-products of the temperature profile predictions are snowpack metamorphism, snow melt evaporation, and snow melt output at the base of the snowpack. SNTHERM.89 addresses processes such as transitions between snow-covered and bare ground, changes in snow properties (i.e., density, grain-size growth, and reflective properties), and the effect of new snow or rainfall.

SNTHERM.89 works by dividing the snow (and soil) layers up into horizontally infinite control volumes. Based on layer temperature, snow properties, and snow surface energy exchange, governing equation for heat and mass balance are solved. A finite-difference scheme is used for the spatial domain, and a Crank-Nicolson method is used with the time steps.

Model input will consist of the atmospheric data, soil temperatures, and snowpack temperatures and characteristics. The modelling results will be verified with the measured snow melt amounts. Output from the snow melt model will be used as input to a vadose zone model.

4.10.2 Snow Melt Monitoring Component Installation

There were three clusters of instruments coupled with pits and their subsurface instrumentation. These clusters were at Pits 1, 3, and 5. These trenches were chosen in an attempt to characterize the research site's topography and exposure (wind and solar). In addition, moving from Pits 5 to 1, showed changes in soil type and profile, and decreased in vadose zone thickness and elevation.

The data collected at each of these sites consisted of a 1 m² snow melt collection pan draining into a subsurface Texas Electronics Rain Gauge, a CSI UDG01 Sonar Snow Depth Sensor, a RM Young #05103 Wind Monitor (for wind speed and direction) at a height of 2 m, a CSI 107 Temperature Probe (with solar radiation/wind shield) at a height of 2 m, an array of CSI 107 Temperature Probes measured the snowpack temperature profile (at adjustable heights of 0, 2.5, 5, 7.5, 10, 15 and 20 cm), and two additional CSI 107B Soil Temperature Probes at 10 and 20 cm below the ground surface. These soil probes were in addition to deeper probes installed during the summer of 1992. Additional temperature probes were not installed at Pit 5 due to the rocky soil and difficulty of installation. Pit 4 had a snow melt collection pan with rain gauge and a snow depth sensor. Pit 2 had no snow melt data instruments, due to its proximity to the Pit 3 cluster.

There was also a 5 m instrument tower. This tower was located near the center of the research site. This instrument cluster collected solar energy data along with wind and vapor pressure profiles. This cluster was not coupled with a pit to avoid wind and solar reflection effects of the pit platforms. Wind speed profiles were being collected by MET 014A Wind Speed Sensors at heights of 0.5, 2 and 5 m. Vapor pressure and atmospheric temperature profiles were collected by

three CSI HMP35C Probes at heights of 0.5, 2, and 4 m. The HMP35C consisted of a Vaisala Capacitive Relative Humidity Sensor and a Fenwal Electronics UUT51J1 Thermistor. Solar instrumentation consisted of two Epply Labs Pyranometers that measured incoming and reflected short-wave solar radiation, an Epply Labs Pyrgeometer that measured incoming long-wave radiation, and a Radiation Energy Balance Systems (REBS) Net Radiometer. The tower location was also equipped with a snow melt collection pan and snow depth sensor.

In addition to these automated instruments, there were manual measurements taken after snow events. A snowstick grid was laid out over the entire research site. The grid size was 10 m X 10 m or 20 m X 20 m depending on the topography. The grid was more dense on the hillside, less dense on the flat areas. The snowsticks were used to estimate the volume of snow on the ground, and with snow density measurements, the water equivalence. Snow density measurements were made at various locations in the site. Four snowboards were constructed and placed along the access road. These were used to measure depth of new snowfalls. All these manual measurements, except some of the density measurements, were taken from the access road, thus reducing time and PPE requirements.

4.10.3 Snow Melt Data

The snow melt modelling data in Section 4.10.2 was recorded every fifteen minutes. This time step was used because of the dynamic nature of snowmelt at RFETS and SNTHERM.⁸⁹ recommendations. Fifteen minute averages were also the standard for wind velocity and direction measurements. Wind velocity and direction were sampled every minute, then averaged over the fifteen minute interval.

All raw data sets were stored on the the RFETS Soils Laboratory Base Station Computer (designated as *Terra*) in the *c:\soi\sno* Directory. Data files were backed-up on a Bernoulli diskette and on the *Land* personal computer in Building 080, Interlocken. In addition, snow data files were periodically archived in RFEDS.

The snow melt study data is included on the SSG_SNBK Bernoulli data diskette in the \SNOW Directory. See Appendix XI, 'Snow Melt Data Location' for details.

4.10.4 Snow Melt Monitoring Component Problems and Solutions

Field installation of the snow melt monitoring system began in late November of 1993. After two weeks of field testing and debugging, the system began collecting field data on December 16, 1993.

As outlined above, the snow melt instrumentation included thirty temperature probes. These probes provided essential data for modelling the energy exchange between the soil, snow, and atmospheric. When the system was first installed, twenty of the probes returned 'out-of-range' values. Voltage checks on the temperature probes revealed that 'grounding noise' was elevating the voltage output slightly above the probes' range. This problem was solved by installing a 100 Ω resistor between the CR-10 temperature probe input channel and analog ground at the CR-10, and unwiring the 107 TP analog grounds at the multiplexer.

Installing the resistor caused the RM Young Wind Direction Readings to become non-linear. This interference occurred when the two measurements were taken with a single-ended voltage measurement, and, thus, were wired into the same CR-10 port. The non-linear response resulted in readings which were no longer in the 0-360° range. A solution has not been found. Possible solutions included installing new 2-conduit wire to the instruments, determining the function to convert the non-linear output to direction in degrees, and trying new wiring/channel arrangements. This wind direction data was not essential for snow melt modelling.

There have been continual problems with the Campbell Scientific SDM-INT8 Interval Timer. This datalogger peripheral was used as a processing interface between the CR-10 and the RM Young Wind Monitors. It converted the RM Young's AC output to wind speed. The output from this device had 'out-of-range' or negative values. Attempts to correct the problem with CR-10 programming and wiring changes have failed. Two of the four RM Young Wind Monitors are being read through the CR-10 pulse channels.

The lack of significant snowfall this season has resulted in a change in the snow temperature profile design. The snowpack's temperature profile was essential for snow melt modelling. The more probes in the snowpack, the greater the modelling data and accuracy. The design consisted

of temperature probes mounted on mono-filament strung between wood posts. Originally, the three sets of seven probes were mounted at a 10 cm interval. The original mounting method did not allow for easy rearranging of the temperature probes. Turnbuckles and hooks were added to the ends of the mono-filament so the probe interval can be easily changed. Currently, the temperature interval is 0, 2.5, 5, 7.5, 10, 15, and 20 cm. If the forecast is for greater than 20 cm of snow, this interval can be changed in less than one minute.

4.11 TDR COMPONENT DATALOGGER AND COMMUNICATIONS

4.11.1 Principles of Campbell Scientific TDR Component Operation

The Campbell Scientific System consisted of data storage, system control, electronic sensors, sampling mechanisms, and communications. This installation included one rain gauge, 14 load cells, 25 temperature probes, 120 soil moisture probes, five vacuum pumps, 15 vacuum line solenoid valves, and telemetry for communication with the laboratory.

A Campbell Scientific Data Logger was used to control the collection of samples and data, and to store data until it was downloaded. The data logger performed its various tasks according to the program that was stored in its memory. The program controlled the execution interval, excitation of sensors (when necessary), specific data to be collected, preliminary operations on data collected, and communication functions. The data logger was able to handle the large number of sensors because it used a system of multiplexers (i.e., AM-416) that increased the number of sensors that could be monitored far beyond the number of control ports on the CR-10. If conditions defined by the program were met, the data logger could trigger mechanical systems for sampling. This was performed through a series of peripheral devices (i.e., SDMX-16) and relays.

The Campbell Scientific System had four different kinds of sensors: (1) precipitation, (2) soil moisture, (3) temperature, and (4) mass of soil water collected. The system had one precipitation gauge. The resolution was 0.254 cm. For improved accuracy, the precipitation gauge was surrounded by a windscreen. Soil moisture was measured with TDR in a configuration provided by Campbell Scientific. Each pit had 24 soil moisture probes resulting in a total of 120 for the system. Several soil temperature probes were installed in each pit, one ambient air temperature,

and one CR-10 panel temperature were measured. Pits 1 through 4 had three load cells each, whereas, Pit 5 had two. The load cells were monitored to measure the data and time of water flow within the soil.

Automated sampling was executed based on the evaluation of soil moisture averages within each pit. For detected soil moisture values corresponding to matric potential between 5-40 kPa the data logger vacuum system was triggered. The pump and solenoid valve corresponding to the location fulfilling the 5-40 kPa criteria were triggered by a three-level process. After a soil moisture value was determined within range, the data logger set at least two ports on the peripheral (SDMX-16) high. Setting SDMX-16 ports high triggered corresponding relays located in the vacuum system enclosure. The relays permitted power to the pumps and solenoids of the layers in the pit that were determined to satisfy the pumping criteria (5-40 kPa). The applied vacuum drew water from the soil through the TSs into a collection system located on the surface.

Communication with the system was maintained through telemetry. The data logger was interfaced with a radio (P-50) through a modem (RFP-95). A second radio (P-50) was located in the laboratory and was interfaced with an IBM PS/2 Model 70 with a modem (RFP-232). Data, real time monitoring, and system checking can be accomplished from the laboratory through the telemetry system.

4.11.2 Campbell Scientific TDR Component Installation and Calibration

CSI Sampling Equipment was installed in conjunction with the excavation of Pits 1 through 5. The data logger (CSI CR-10), radio (Radius P-50), modem (CSI RFP-95), cable tester (Tektronix 1502B), control port module (CSI SDM-CD16), and power supply were initially placed in the field on a wooden platform close to Pit 1. The platform was originally a staircase for one of the subcontractor trailers. It was moved to the field and specifically modified and reinforced to serve as the central hardware platform, or CR-10 platform. The CR-10, radio, modem, and SDM-CD16 were all incased in a single weatherproof enclosure (CSI ENC 12/14). The cable tester was housed in its own enclosure (CSI ENC TDR), while the power supply was located under the CR-10 platform in a generic battery case. A total of three, Level 3 TDR probe multiplexers (CSI SDMX50) and one load cell/temperature probe multiplexer (CSI AM-416) were placed at Pit 1.

Each of SDMX50 multiplexers and the AM-416 multiplexer were placed in weatherproof enclosures (CSI ENC 10/12). The multiplexers were then mounted on the Pit 1 platform at the South end of Pit 1. The Pit 1 platform was originally a target holder for the old shooting range and was reinforced and moved to Pit 1. Once the pit was completed the vacuum pump enclosure, TS collection bottle enclosure, and the three photo-voltaic panels (CSI MSX18R) were installed. The two enclosures were placed on top of the back-filled pit and the photo-voltaic panels were mounted on the platform with the multiplexers.

After Pit 1 was initially tested, the CR-10 platform was moved to a location central to all the pits. The field antenna (Decibel DB536 @ 403 MHz) was installed approximately 6.096 m west of the CR-10 platform. An SDMX50 multiplexer was added to the CR-10 platform and served as the level 1 TDR multiplexer. Another ENC 12/14 enclosure was added to house the original SDM-CD16, plus one additional SDM-CD16.

As additional pits were completed, each pit received a standard allocation of equipment that consisted of three, Level 3 SDMX50's, a vacuum pump enclosure, a tension sample collection bottle enclosure, and three photo voltaic panels. Four standardized wooden mounting frames were constructed for Pits 2 through 5. The frames were placed at strategic locations next to each pit. Pipes of 3.81 cm O.D. were attached to the frames and used for mounting the enclosures and photo-voltaic panels. The enclosures and photovoltaic panels were mounted with U-bolts. This allowed better positioning of the enclosures and easy adjustment of the photo voltaic panels for seasonal changes in sunlight. The AM-416 multiplexers were installed at Pits 3 and 5. Pit 3 received its own level two SDMX50 multiplexer. The Level 2 SDMX50 Multiplexers for Pits 1, 2, 4, and 5 were installed midway between Pits 1 and 2, and between Pits 4 and 5 for a total of three, Level 2 SDMX50 Multiplexers.

All of the sensors in the field were directly or indirectly hooked to the CR-10. Most of the connections were indirect, through a multiplexer. From the actual probe to the multiplexer, each sensor cable was routed through conduit. Two types of conduit were used: (1) a 1.905 cm flexible blue plastic, and (2) a white rigid PVC in a variety of sizes. Junction boxes were constructed in order to merge all the conduits at each multiplexer. Each multiplexer enclosure had two inlet/outlet ports. The junction boxes varied in size, shape, and port configuration dependent on the application. All junction boxes were constructed with 1.27 cm clear Lucite. All inputs and

outputs to a single multiplexer were routed through its respective junction box, and reduced to two conduits matching the multiplexer enclosure ports.

The office in Trailer T891R served as the remote station for the CSI Sampling System. Trailer T891M is the present location of the Soils Laboratory and CSI Sampling System remote station. The equipment consisted of an IBM PS/2 Model 70 with a serial communications card, CSI communications software, modem (CSI RFP-232), radio (Radius P50), and an antenna (Celwave BA-6012-0). The antenna was mounted on a 3.81 cm O.D. steel pipe attached to the side of T891R. The pipe served as a mounting location and ground. The modem had room for internal installation of the radio and was connected to the computer with an RS-232 interface.

4.11.3 Campbell Scientific TDR Component Problems and Solutions

Overall, the Campbell Scientific datalogger and datalogger peripherals have proven to be very reliable. Details on the performance of individual field instruments can be found in referenced in Appendices V, VI, VII, and IX and in Sections 4.2.4, 4.3.4, 4.4.4, 4.6.4, 4.7.4, 4.8.4, 4.9.2, and 4.10.4. The rest of Section 4.11.3 discusses the problems encountered and their solutions.

Due to lead lengths (i.e., length of cable between datalogger and instrument) of up to 60 m, the CR-10 was timed-out before receiving data from the instrument being sampled. To correct this problem, a special programmed read only memory (PROM) programmed by CSI needed to be installed in the CR-10.

Voltage drops in the 12V power supply occurred occasionally, especially during cold weather. The power supply consists of two marine 12V batteries (in series) connected to solar panels. Increasing the number of solar panels to four solved the problem.

Problems with the TDR multiplexer design were encountered. This multiplexer consisted of a bulkhead 'n' chassis (BNC) cable connector connected directly onto the multiplexer printer circuit board. This connection was found to be weak, and would occasionally break. No solution was found, other than exercising great care when installing or servicing.

4.11.4 Telemetry Installation

Data collected by telemetry shall follow guidelines set forth in EMD SOP GT.20; "Procedures for Soil Interstitial Water Sampling and Sampler Installation," EMD Manual Operation SOP, Rev. 2; Dated: March 1, 1992. Section 8.2.4, "Soil Moisture Data."

4.11.5 Telemetry Problems and Solutions

The telemetry was successful and maintenance free. Early transmission problems were corrected by changing from an omni-directional antenna to Yagi directional antennas. The TDR and snow field components used telemetry. The only problem was caused by interference with a neighboring frequency. The frequency, used by the Air Sampling Group, was much stronger and automatically triggered every 15 minutes. If the Soil Group data transmission required more than 15 minutes to finish, it had to be stopped and restarted after the Air Sampling transmission was completed.

4.12 Data Storage

4.12.1 Location of Collected Data

All TDR data files are stored on the *Terra* personal computer at the Soils Laboratory (T891E) at RFETS. TDR raw data and database files are stored in the *C:\Soil* Directory. *TDR raw data files are stored as *.TDR* and database files as **.DBF*. One complete set of backups are stored on the Soil Group's *Land* personal computer in Building 080, Interlocken. Two other sets of backups are stored on Bernoulli disks at the Soils Laboratory and in Building 080. In addition, RFEDS periodically archives the TDR data files (in its original format) (See Fig. 4.12.1-1). All data collected by the snow monitoring component is stored on the *Terra* PC in the *C:\soil\sno* Directory. Snow raw data is stored as **.sno*. One complete set of backups are stored on the Soil Group's *Land* personal computer in Building 080, Interlocken. Another set of backups are stored on Bernoulli disks at the Soils Laboratory. In addition, RFEDS periodically archives the snow data files (in its original format).

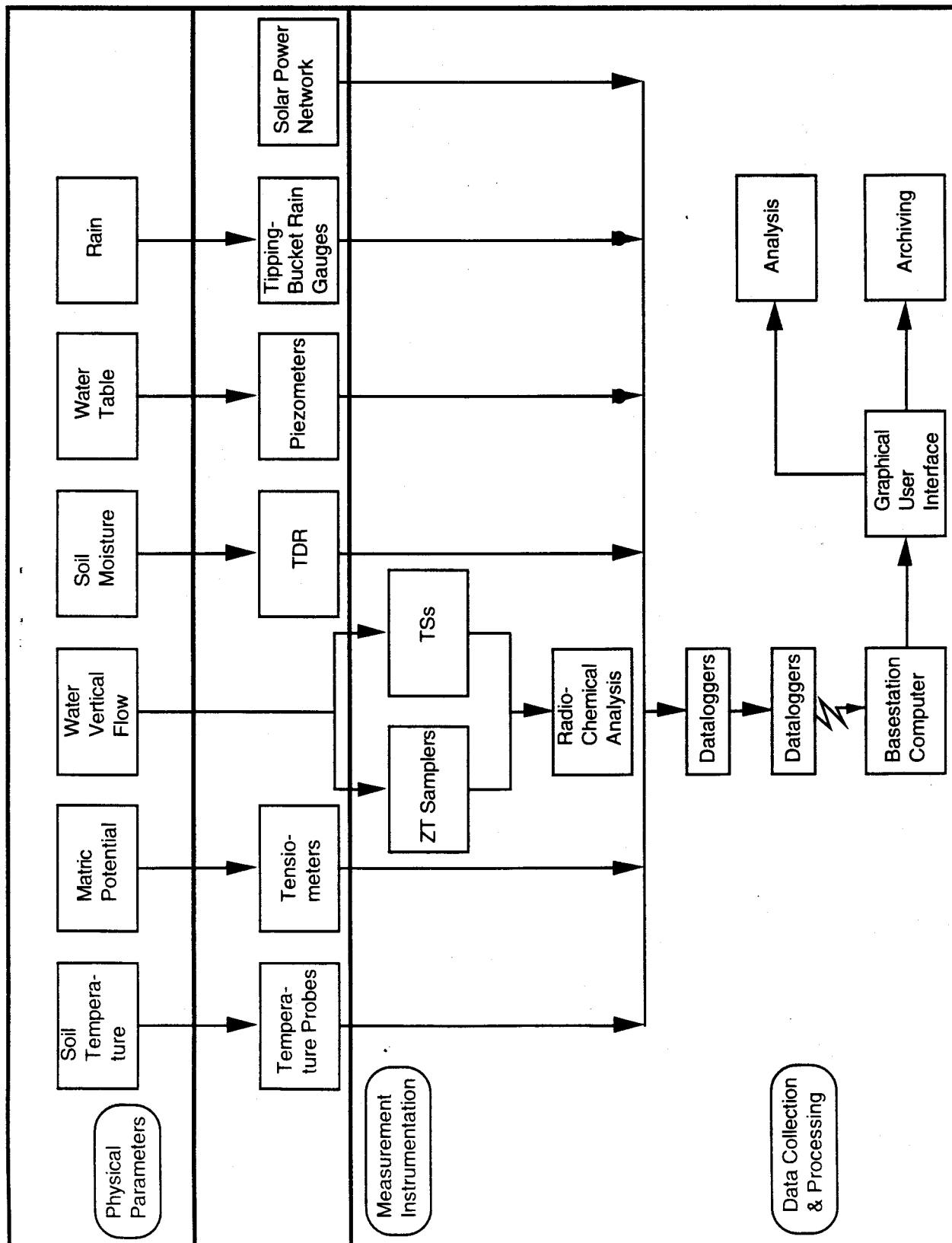


Figure 4.12.1-1 Schematic Diagram of SWMS

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Appendix I
Acronym List

Am	Americium
ATV	All-Terrain Vehicle
BNC	Bulkhead 'N' Chassis
Co-PI	Collaborating Principle Investigators
CSI	Campbell Scientific, Inc.
DC	Deep-Cycle
EM	Electromagnetic
ER	Environmental Restoration
ERD	Earth Resources Division
ES&T	Environmental Science and Technology
gm	Gravitational Measurement
GPR	Ground Penetrating Radar
H&S	Health and Safety
I.D.	Interior Diameter
L ¹ F	Lateral Flow
lpm	liters per minute
mV	Output Voltage
PI	Principle Investigator
PM	Project Manager
PROM	Program Read Only Memory
PTFE	Polyethylene Tetrafluoride
Pu	Plutonium
PVC	Polyvinylchloride
REBS	Radiation Energy Balance Systems
RFEDS	Rocky Flats Environmental Database System
RFETS	Rocky Flats Environmental Technology Site

RFP	Rocky Flats Plant
SOP	Standard Operating Procedure
SSSP	Surficial Soil Sampling Program
TDR	Time Domain Reflectometry
TS	Tension Sampler
TSSS	Tension Soil Solution Sampler
V	Voltage
VAC	Voltage Alternating Current
ZT	Zero Tension

Appendix II

OU2 Pit Locations and Line Profiles

 MERRICK & COMPANY JOB #282-7597

WOODWARD-CLYDE FEDERAL SERVICES

OU2 TRENCH LOCATIONS AND LINE PROFILES

DATE OF SURVEY: SEPTEMBER 24, 1992

NAD 27 COLORADO CENTRAL ZONE
 STATE PLANE COORDINATES

#	EASTING	NORTHING	ELEV	DESCRIPTOR
20	2086848.5359	748865.5628	5916.96	TR1 CENTER @ INST. SENSOR
21	2086849.8214	748871.3216	5917.11	N. END PIT TR1
22	2086844.1954	748858.0816	5917.03	S. END PIT TR1
23	2086835.0281	749053.0927	5955.34	TOP EDGE RIDGE
24	2086840.2133	748990.4516	5931.80	GB @ TOE SLOPE
25	2086847.2368	748895.9604	5919.05	GB @ FL E-W DITCH
26	2086847.2721	748887.6019	5919.94	GB
27	2086847.8196	748882.1705	5918.84	GB
28	2086850.2545	748847.3487	5916.30	GB
29	2086850.5539	748829.0129	5917.06	GB
30	2086851.9366	748791.9066	5914.13	GB
31	2086851.7728	748783.6934	5912.60	GB @ N. EDGE ROAD
32	2086751.4611	748900.5525	5925.21	TR2 CENTER @ INST. SENSOR
33	2086744.1518	748893.7399	5924.91	S. END TR2
34	2086756.8398	748905.8638	5925.60	N. END TR2
35	2086719.8783	749036.6787	5959.37	TOP EDGE RIDGE
36	2086740.2902	748941.6737	5931.15	GB @ TOE SLOPE
37	2086748.8043	748912.0881	5926.27	GB
38	2086762.3836	748863.4128	5921.91	GB
39	2086765.6670	748859.5121	5922.20	GB
40	2086774.4461	748827.9035	5920.37	GB
41	2086776.4721	748821.1721	5918.86	GB @ FL E-W DITCH
42	2086779.2567	748813.5315	5920.14	GB
43	2086785.5799	748802.2972	5918.44	GB @ N. EDGE ROAD
44	2086696.8030	748909.9824	5930.16	TR3 CENTER @ INST. SENSOR
45	2086691.3514	748905.1428	5929.95	W. END TR3
46	2086703.5756	748915.4108	5930.12	E. END TR3
47	2086632.2597	749012.9307	5963.66	TOP EDGE RIDGE
48	2086645.8010	748994.8175	5958.93	GB ON SLOPE
49	2086685.7265	748929.9204	5933.64	GB @ TOP SLOPE
50	2086711.5644	748880.4046	5925.55	GB
51	2086740.6389	748832.5974	5923.51	GB
52	2086752.5137	748809.6574	5920.93	GB @ N. EDGE ROAD
53	2086567.1450	748918.0947	5945.26	TR5 CENTER @ INST. SENSOR

Path: E:\

File: TRCH_TSP.RPT

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Page 2

2086561.9786	748914.3091	5944.89	W. END TR5
55 2086574.0160	748923.5229	5945.41	E. END TR5
56 2086533.9042	748981.6075	5964.40	TOP EDGE RIDGE
57 2086540.6854	748965.6347	5961.46	GB
58 2086564.0188	748924.0938	5946.05	GB @ TOE SLOPE
59 2086574.5903	748905.4541	5942.26	GB
60 2086596.7367	748875.8696	5934.49	GB
61 2086626.3330	748827.6243	5929.57	GROUND @ N. EDGE ROAD
62 2086634.0450	748883.9038	5932.66	TR4 CENTER @ INST. SENSOR
63 2086632.2570	748874.0185	5932.12	S. END TR4
64 2086635.2652	748893.4410	5933.10	N. END TR4
65 2086591.8497	748998.3537	5963.61	TOP EDGE RIDGE
66 2086596.8632	748981.3474	5960.34	GB ON SLOPE
67 2086626.4959	748900.4337	5934.01	GB @ TOE SLOPE
68 2086650.9908	748845.8502	5929.24	GB
69 2086655.3787	748835.6692	5927.36	GB
70 2086660.4164	748824.0126	5927.06	GB @ N. EDGE ROAD
71 2086502.7675	748893.5577	5944.65	GROUND
72 2086565.8363	748889.3516	5940.02	GB
73 2086612.0576	748885.6357	5933.73	GB
74 2086643.1555	748884.1923	5932.05	GB
75 2086784.8460	748879.1835	5921.30	GB
76 2086815.3166	748875.3490	5919.33	GB @ FL E-W DITCH
77 2086778.5359	748877.6975	5921.68	GRND @ ORANGE PIN FLAG #200
78 2086681.2230	748858.9515	5927.44	GRND @ YELLOW PIN FLAG #-100
79 2086561.6032	748873.0279	5937.99	GRND @ YELLOW PIN FLAG #-20
80 2086502.1233	748880.2305	5943.65	GRND @ ORANG PIN FLAG #-80/0
81 2086503.9641	748930.0225	5951.74	GRND @ YELLOW PIN FLAG NW COR Y50
82 2086562.8505	748922.6431	5945.87	GRND @ YELLOW PIN FLAG (NO #)
83 2086677.6588	748928.6255	5934.29	GRND @ ORANGE PIN FLAG #100
84 2086783.4241	748946.6432	5928.32	GRND @ ORANGE PIN FLAG #200/2100
85 2086664.2903	748843.4431	5928.09	GRND @ RADIO ANTENNA
86 2086690.2480	748826.0771	5925.99	GRND @ MAIN INST. PANEL STATION

 TERRICK & COMPANY JOB #282-7597

WOODWARD-CLYDE FEDERAL SERVICES

OU2 TRENCH LOCATIONS AND LINE PROFILES

DATE OF SURVEY: SEPTEMBER 24, 1992

NAD 27 COLORADO CENTRAL ZONE
 MODIFIED (GROUND) STATE PLANE COORDINATES

N. #	EASTING	NORTHING	ELEV	DESCRIPTOR
20	2087382.4861	749057.1713	5916.96	TR1 CENTER @ INST. SENSOR
21	2087383.7719	749062.9316	5917.11	N. END PIT TR1
22	2087378.1445	749049.6882	5917.03	S. END PIT TR1
23	2087368.9749	749244.7492	5955.34	TOP EDGE RIDGE
24	2087374.1614	749182.0921	5931.80	GB @ TOE SLOPE
25	2087381.1868	749087.5767	5919.05	GB @ FL E-W DITCH
26	2087381.2221	749079.2160	5919.94	GB
27	2087381.7697	749073.7832	5918.84	GB
28	2087384.2052	749038.9526	5916.30	GB
29	2087384.5047	749020.6121	5917.06	GB
30	2087385.8877	748983.4962	5914.13	GB
31	2087385.7238	748975.2809	5912.60	GB @ N. EDGE ROAD
32	2087285.3865	749092.1700	5925.21	TR2 CENTER @ INST. SENSOR
33	2087278.0753	749085.3556	5924.91	S. END TR2
34	2087290.7666	749097.4826	5925.60	N. END TR2
35	2087253.7956	749228.3310	5959.37	TOP EDGE RIDGE
36	2087274.2127	749133.3017	5931.15	GB @ TOE SLOPE
37	2087282.7291	749103.7085	5926.27	GB
38	2087296.3118	749055.0208	5921.91	GB
39	2087299.5961	749051.1191	5922.20	GB
40	2087308.3774	749019.5024	5920.37	GB
41	2087310.4040	749012.7693	5918.86	GB @ FL E-W DITCH
42	2087313.1892	749005.1267	5920.14	GB
43	2087319.5140	748993.8895	5918.44	GB @ N. EDGE ROAD
44	2087230.7144	749101.6022	5930.16	TR3 CENTER @ INST. SENSOR
45	2087225.2614	749096.7614	5929.95	W. END TR3
46	2087237.4887	749107.0320	5930.12	E. END TR3
47	2087166.1546	749204.5770	5963.66	TOP EDGE RIDGE
48	2087179.6994	749186.4591	5958.93	GB ON SLOPE
49	2087219.6351	749121.5454	5933.64	GB @ TOP SLOPE
50	2087245.4796	749072.0169	5925.55	GB
51	2087274.5615	749024.1975	5923.51	GB
52	2087286.4393	749001.2516	5920.93	GB @ N. EDGE ROAD
53	2087101.0232	749109.7166	5945.26	TR5 CENTER @ INST. SENSOR

54	2087095.8555	749105.9301	5944.89	W. END TR5
55	2087107.8960	749115.1462	5945.41	E. END TR5
56	2087067.7739	749173.2457	5964.40	TOP EDGE RIDGE
57	2087074.5569	749157.2688	5961.46	GB
58	2087097.8962	749115.7173	5946.05	GB @ TOE SLOPE
59	2087108.4704	749097.0728	5942.26	GB
60	2087130.6225	749067.4808	5934.49	GB
61	2087160.2264	749019.2231	5929.57	GROUND @ N. EDGE ROAD
62	2087167.9404	749075.5170	5932.66	TR4 CENTER @ INST. SENSOR
63	2087166.1519	749065.6292	5932.12	S. END TR4
64	2087169.1609	749085.0566	5933.10	N. END TR4
65	2087125.7343	749189.9962	5963.61	TOP EDGE RIDGE
66	2087130.7490	749172.9855	5960.34	GB ON SLOPE
67	2087160.3894	749092.0511	5934.01	GB @ TOE SLOPE
68	2087184.8905	749037.4537	5929.24	GB
69	2087189.2795	749027.2700	5927.36	GB
70	2087194.3185	749015.6105	5927.06	GB @ N. EDGE ROAD
71	2087036.6293	749085.1734	5944.65	GROUND
72	2087099.7142	749080.9662	5940.02	GB
73	2087145.9474	749077.2493	5933.73	GB
74	2087177.0532	749075.8055	5932.05	GB
75	2087318.7799	749070.7955	5921.30	GB
76	2087349.2583	749066.9600	5919.33	GB @ FL E-W DITCH
77	2087312.4682	749069.3091	5921.68	GRND @ ORANGE PIN FLAG #200
78	2087215.1305	749050.5583	5927.44	GRND @ YELLOW PIN FLAG #-100
79	2087095.4800	749064.6384	5937.99	GRND @ YELLOW PIN FLAG #-20
80	2087035.9849	749071.8428	5943.65	GRND @ ORANG PIN FLAG #-80/0
81	2087037.8262	749121.6475	5951.74	GRND @ YELLOW PIN FLAG NW COR Y50
82	2087096.7277	749114.2662	5945.87	GRND @ YELLOW PIN FLAG (NO #)
83	2087211.5654	749120.2501	5934.29	GRND @ ORANGE PIN FLAG #100
84	2087317.3577	749138.2725	5928.32	GRND @ ORANGE PIN FLAG #200/2100
85	2087198.1934	749035.0459	5928.09	GRND @ RADIO ANTENNA
86	2087224.1578	749017.6755	5925.99	GRND @ MAIN INST. PANEL STATION

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Page 1

RICK & COMPANY JOB #282-7597

WOODWARD-CLYDE FEDERAL SERVICES

OU2 TRENCH LOCATIONS AND LINE PROFILES

DATE OF SURVEY: SEPTEMBER 24, 1992

ROCKY FLATS PLANT GRID COORDINATE SYSTEM

#	EASTING	NORTHING	ELEV.	DESCRIPTOR
0	23739.4266	35873.3633	5916.96	TR1 CENTER @ INST. SENSOR
1	23740.7314	35879.1193	5917.11	N. END PIT TR1
2	23735.0603	35865.8946	5917.03	S. END PIT TR1
3	23726.5347	36060.9848	5955.34	TOP EDGE RIDGE
4	23731.5143	35998.3109	5931.80	GB @ TOE SLOPE
5	23738.2276	35903.7728	5919.05	GB @ FL E-W DITCH
6	23738.2353	35895.4121	5919.94	GB
7	23738.7650	35889.9775	5918.84	GB
8	23741.0855	35855.1390	5916.30	GB
9	23741.3244	35836.7976	5917.06	GB
0	23742.5849	35799.6774	5914.13	GB
1	23742.3939	35791.4627	5912.60	GB @ N. EDGE ROAD
2	23642.4430	35908.6824	5925.21	TR2 CENTER @ INST. SENSOR
3	23635.1094	35901.8922	5924.91	S. END TR2
4	23647.8406	35913.9772	5925.60	N. END TR2
5	23611.3019	36044.9470	5959.37	TOP EDGE RIDGE
6	23631.4051	35949.8508	5931.15	GB @ TOE SLOPE
7	23639.8237	35920.2296	5926.27	GB
8	23653.2456	35871.4973	5921.91	GB
9	23656.5170	35867.5848	5922.20	GB
0	23665.1939	35835.9393	5920.37	GB
1	23667.1982	35829.1995	5918.86	GB @ FL E-W DITCH
2	23669.9582	35821.5478	5920.14	GB
3	23676.2459	35810.2898	5918.44	GB @ N. EDGE ROAD
4	23587.8024	35918.2951	5930.16	TR3 CENTER @ INST. SENSOR
5	23582.3334	35913.4723	5929.95	W. END TR3
6	23594.5946	35923.7025	5930.12	E. END TR3
7	23523.5829	36021.4824	5963.66	TOP EDGE RIDGE
8	23537.0678	36003.3199	5958.93	GB ON SLOPE
9	23576.7890	35938.2747	5933.64	GB @ TOP SLOPE
0	23602.4698	35888.6612	5925.55	GB
1	23631.3937	35840.7460	5923.51	GB
2	23643.1957	35817.7610	5920.93	GB @ N. EDGE ROAD
3	23458.1387	35926.8376	5945.26	TR5 CENTER @ INST. SENSOR
4	23452.9585	35923.0682	5944.89	W. END TR5

Path: B:\

File: TRCH_LOC.RPT

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Page 2

23465.0294	35932.2445	5945.41	E. END TR5
23425.0993	35990.4761	5964.40	TOP EDGE RIDGE
23431.8295	35974.4769	5961.46	GB
23455.0315	35932.8486	5946.05	GB @ TOE SLOPE
23465.5441	35914.1693	5942.26	GB
23487.5984	35884.5043	5934.49	GB
23517.0428	35836.1491	5929.57	GROUND @ N. EDGE ROAD
23524.9426	35892.4173	5932.66	TR4 CENTER @ INST. SENSOR
23523.1215	35882.5354	5932.12	S. END TR4
23526.1946	35901.9528	5933.10	N. END TR4
23483.1147	36007.0352	5963.61	TOP EDGE RIDGE
23488.0732	35990.0080	5960.34	GB ON SLOPE
23517.4462	35908.9762	5934.01	GB @ TOE SLOPE
23541.7669	35854.2982	5929.24	GB
23546.1223	35844.1001	5927.36	GB
23551.1228	35832.4240	5927.06	GB @ N. EDGE ROAD
23393.6641	35902.5071	5944.65	GROUND
23456.7348	35898.0917	5940.02	GB
23502.9554	35894.2222	5933.73	GB
23534.0563	35892.6757	5932.05	GB
23675.7657	35887.1978	5921.30	GB
23706.2313	35883.2617	5919.33	GB @ FL E-W DITCH
23669.4491	35885.7322	5921.68	GRND @ ORANGE PIN FLAG #200
23572.0500	35867.3029	5927.44	GRND @ YELLOW PIN FLAG #-100
23452.4467	35881.7779	5937.99	GRND @ YELLOW PIN FLAG #-20
23392.9757	35889.1787	5943.65	GRND @ ORANG PIN FLAG #-80/0
23394.9814	35938.9771	5951.74	GRND @ YELLOW PIN FLAG NW COR Y50
23453.8582	35931.4014	5945.87	GRND @ YELLOW PIN FLAG (NO #)
23568.7150	35937.0061	5934.29	GRND @ ORANGE PIN FLAG #100
23674.5663	35954.6791	5928.32	GRND @ ORANGE PIN FLAG #200/2100
23555.0618	35851.8465	5928.09	GRND @ RADIO ANTENNA
23580.9687	35834.3905	5925.99	GRND @ MAIN INST. PANEL STATION

3 N= 2821-7547

SEPT. 24, 1992
CLEAN 20-85°
CACHA

CHILDS, ROGER S. TH. 9
BUTEMAN, RICH. J. TH. 14

ZEISS ELTA 3

SN

151

ELEV = 5912.30
HI = 5⁵⁴

w/o. 00.00

SKETCH PAGE 53

	HORIZ	ZENITH	SD	HT	NOTES	
0	233-14-24	89-51-07	1996.54	6.12	TRUNKY TR1, CENTER INST. CENTER (5916.505)	5916.98
1	233-21-10	89-50-53	2000.94	"	N END PIT TR1	5917.11
2	233-01-33	89-50-54	1992.15	"	S END PIT TR1	5917.03
3	LINE	PRO FILE		"		
4	235-21-11	89-51-00	2168.67	"	TAP EDGE RITE	(PRO FILE) 5955.34
5	234-42-06	89-27-26	2110.35	"	GRIP DE BRUN TOE HOLE	5931.80
6	233-32-44	89-17-12	2023.25	"	" " " " " " " "	" " " " " " " "
7	233-30-54	89-46-13	2016.42	"	" " " " " " " "	" " " " " " " "
8	233-27-13	89-47-58	2011.40	"	GRAPPE HERRAN	5918.84
9	233-01-32	89-52-11	1979.82	"	" " " " " " " "	" " " " " " " "
10	232-46-11	89-50-47	1963.73	"	" " " " " " " "	" " " " " " " "
11	232-15-32	89-55-51	1930.89	"	" " " " " " " "	" " " " " " " "
12	232-07-53	89-58-34	1923.58	"	" " " " " " " "	" " " " " " " "

DATE	LINE	HT	SD	Notes
10 #303	EL = 5912.30			
SH 1705	HI = 5.54			
	W/O 00.00			
201-22-27	2511.2	2075.69		TRENCH (TR2) CENTER LINE 5924.91
201-26-27	2511.2	2073.66		S. END TR2 5925.60
201-34-27	2511.2	2077.47		N. END TR2 5925.60
201-37-27	2511.2	2079.46		TOP EDGE FIDGE (FIDGE) 5959.37
201-41-27	2511.2	2016.75		GRADE BREAK 5926.27
201-48-27	2511.2	2086.95		GRADE BREAK 5921.91
201-55-27	2511.2	2038.25		" " 5922.20
201-62-27	2511.2	2033.21		" " 5920.37
201-69-27	2511.2	2001.66		" " 5920.37
201-76-27	2511.2	1994.86		" " E-W DITCH 5918.86
201-83-27	2511.2	1986.90		GRADE BREAK 5920.14
201-90-27	2511.2	1974.01		" " N. EDGE ROAD 5918.44

9/24/92

40465

Kerry

LYLE

LINE

77

EL = 5912.30

HI = 5.54

W/0.00.00

SKETCH

P. 53

Horiz	Zero	SD	HT	Notes	Center
230-14-14	89-30-23	2112.49	6.12	TRENNING TRB	5930.16
230-02-31	89-30-28	2111.32	"	W. END TRB	5929.95
230-28-16	89-30-13	2113.48	"	E. END TRB	5930.12
LINE PROFILE					
230-14-52	83-11-15	2234.55	"	TOP EDGE FENCE	5963.66
230-17-33	83-46-47	2211.90	"	GRADE BREAK	5958.93
230-16-15	89-21-57	2135.30	"	GRADE BREAK	5933.58
230-08-45	89-33-11	2079.56	"	GRADE BREAK	5925.55
230-06-59	89-40-27	2023.59	"	"	5923.51
230-03-05	89-31-13	1997.39	"	"	EDGE ROAD 5920.73

WOODWAY AVEY P. 3
 CUYUE - DIST
 LINE PROFILE

# 303	EL = 5912.30	
# 1705	HI = 5.54	
	W/O 0:00.00	
HORIZ	REN.	50
227-28-56	89-07-32	2191.32
227-18-53	89-08-07	2191.19
227-22-39	89-07-19	2191.84
LINE	PROFILE	
227-22-59	38-40-07	2262.80
227-32-33	88-44-01	2245.75
227-20-19	89-06-28	2198.04
227-27-04	89-11-55	2174.65
227-28-65	89-23-34	2139.61
227-23-12	89-30-41	2083.06

SKETCH P. 53

HT	NOTES	5945.26
6.12	TRENER / TRS CENTERLINE	5945.26
"	W. END TRS	5944.87
"	E. END TRS	5945.41
"	TOP EDGE RIDGE (P. 227-24)	5964.46
"	GRADE AREA	5961.46
"	" TOP	5946.05
"	GRADE BREF. X	5942.26
"	"	5934.49
"	GROUND N. EDGE ROAD	5949.57

4/24/92

W1000 up 'N
KEY P. LINE
FILES

@ #303 EL=5912.30

#1705 HI= 5 54

W/O.00.00

Sketch Pg. 53

Horiz	Vert	SD	HT	Notes	HT
228-15-49	89-20-16	2125.01	6.12	TRENCH / TRP	5932.66
228-14-25	89-27-02	2117.86	"	S. END TRA	5932.12
228-36-07	89-25-41	2132.27	"	N. END TRA	5933.10
229-10-34	89-20-41	2144.19	"	TOP EDGE KIDSE	5963.61
229-22-36	89-45-06	2127.16	"	GRADE BREAK	5960.34
228-30-39	89-24-29	2142.98	"	GRADE BREAK TO: SKIRT	5934.01
228-13-47	89-31-15	2084.00	"	GRADE BREAK	5929.24
228-10-17	89-34-13	2073.10	"	"	5927.36
228-06-15	89-34-33	2060.63	"	"	5927.06
225-44-52	89-08-53	2209.19	"	GROUND	5944.65
227-01-07	89-15-17	2168.53	"	GRADE BREAK	5940.02
227-58-06	89-24-47	2135.58	"	"	5933.73
228-38-19	89-27-11	2120.18	"	"	5932.05
231-51-59	89-47-21	2040.15	"	"	5921.30
232-35-15	89-47-22	2021.48	"	"	5919.33

E W DITCH

VIEW \$ NIC PERIMETER & MISC.

@ #1303 EL = 5912.30
 #1705 HI = 551
 W/O 00.00

HORIZ	ZEN	SD
231-41-34	89-43-23	2042.13
229-07-30	89-34-48	2028.03
226-40-28	89-18-17	2152.71
225-31-39	89-10-14	2198.90
226-18-57	88-58-41	2232.92
227-27-31	89-06-44	2197.52
230-04-13	89-23-52	2138.53
232-46-19	89-32-58	2022.26

MISC.

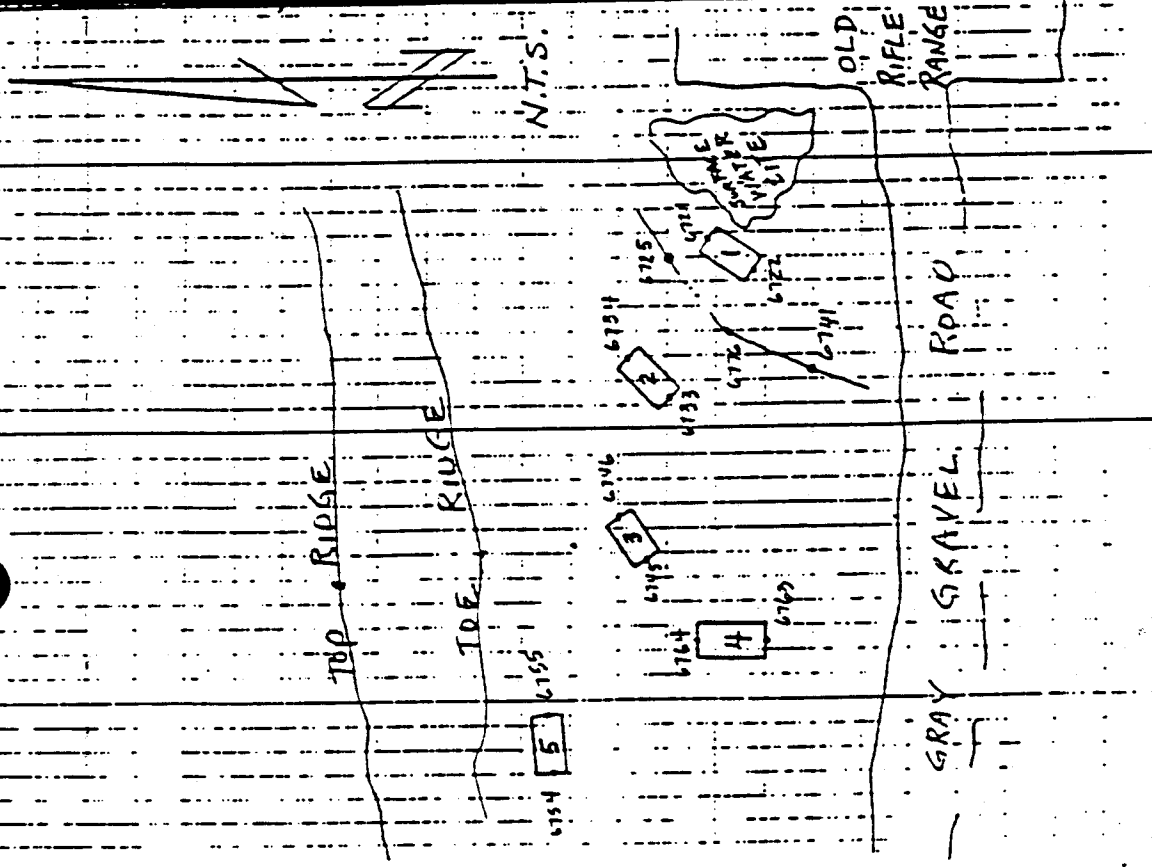
229-29-45	89-33-01	2074.53
		2045.44
228-49-35	89-32-48	2042.64

* SHOTS FOR PERIMETER OF SEONIC
 AREA WERE TAKEN AS INSTRUCTED BY
 BILL FROMEYAK OF WOODWARD CLYDE.
 SKETCH P. 53

HT	NOTES	5912.30
6.12	GROUND PIN FLARE #200 PERIMETER	5912.30
"	" C PIN FLARE #100? ANGLE FROM FLARE	5927.14
"	" " #20 ANGLE FROM FLARE	5937.89
"	" C ORANGE PIN FLARE #803 SW COR 5943.65	
"	" GROUND PIN FLARE NW COR 5951.74	
"	" " NO NUMBER ANGLE FROM FLARE	5945.87
"	" C ORANGE #1000 ANGLE FROM FLARE	5934.29
"	" GROUND PIN FLARE #200 NE COR 5928.52	
"	GROUND RADIO ANTENNA	5928.01
8.12	GROUND C MAIN INST. PANEL STATION	5925.78

SKETCH MONITOR AREA

PITS ARE ALL APPROX 6' W X 10' L



Appendix III

Rocky Flats Field Activities Report Pit Sampling

ROCKY FLATS FIELD ACTIVITIES REPORT PIT & TRENCH SAMPLING

PROJECT NUMBER 4006
PROJECT NAME 002
TRENCH NUMBER T12-1
SAMPLERS 6/8/92 LVS mZL

DATE 6/8/92

COORDINATES N
E

DEPTH (cm)	HORIZON	
↓	A	* 3T10 * 6T9 * 9T8 * 12T7
16	AB	* 13T6
27		* 24T5
BtKI		* 36T4 * 48T3
58		
BtgK		
76		* 72T2
Btg		* 96T1
103		
2Btg		
123+		

T1= 1341	T9= 1425	T17= 1630	T25=	T33=	T41=
T2= 1353	T10= 1430	T18=	T26=	T34=	T42=
T3= 1356	T11= 1445	T19=	T27=	T35=	T43=
T4= 1401	T12= 1543	T20=	T28=	T36=	T44=
T5= 1406	T13= 1546	T21=	T29=	T37=	T45=
T6= 1410	T14= 1559	T22=	T30=	T38=	T46=
T7= 1416	T15= 1610	T23=	T31=	T39=	T47=
T8= 1422	T16= 1618	T24=	T32=	T40=	T48=

TR00XXX WCUZ

Radiation Samples

Sample #	Depth (cm)	Horizon	Time	Comments
341	96	Btg	1347	RADONUCLIDES (PB, RC) w/ RAD SCREEN
342	72	Btgk	1353	
343	48	Btkf	1356	
344	36	Btkf	1401	
345	24	AB	1406	
346	18	AB	1410	
347	12	A	1416	
348	9	A	1422	
349	6	A	1425	
350	3	A	1430	
357			1445	INSATE

Trench Samples

TIME

DEPTH (cm)

Sample #	Depth (cm)	Horizon	Time (hrs)	Comments
351	1543	A	0-16	1. GENERAL SOIL PARAMETERS
↓	↓	↓	↓	2. CLAY MINERALS
↓	↓	↓	↓	3. SPECIFIC SURFACE
↓	↓	↓	↓	4. BULK DENSITY
↓	↓	↓	↓	5. SEQUENTIAL EXTRACTION
352	1546	AB	16-27	1.
↓	↓	↓	↓	2.
↓	↓	↓	↓	3.
↓	↓	↓	↓	4.
↓	↓	↓	↓	5.
353	1559	Btkf	27-58	1.
↓	↓	↓	↓	2.
↓	↓	↓	↓	3.
↓	↓	↓	↓	4.
↓	↓	↓	↓	5.
354	1610	Btgk	58-76	1.
↓	↓	↓	↓	2.
↓	↓	↓	↓	3.
↓	↓	↓	↓	4.
↓	↓	↓	↓	5.
355	1618	Btg	76-103	1.
↓	↓	↓	↓	2.
↓	↓	↓	↓	3.
↓	↓	↓	↓	4.
↓	↓	↓	↓	5.
356	1630	2Btg	103-123+	1.
↓	↓	↓	↓	2.
↓	↓	↓	↓	3.
↓	↓	↓	↓	4.
↓	↓	↓	↓	5.

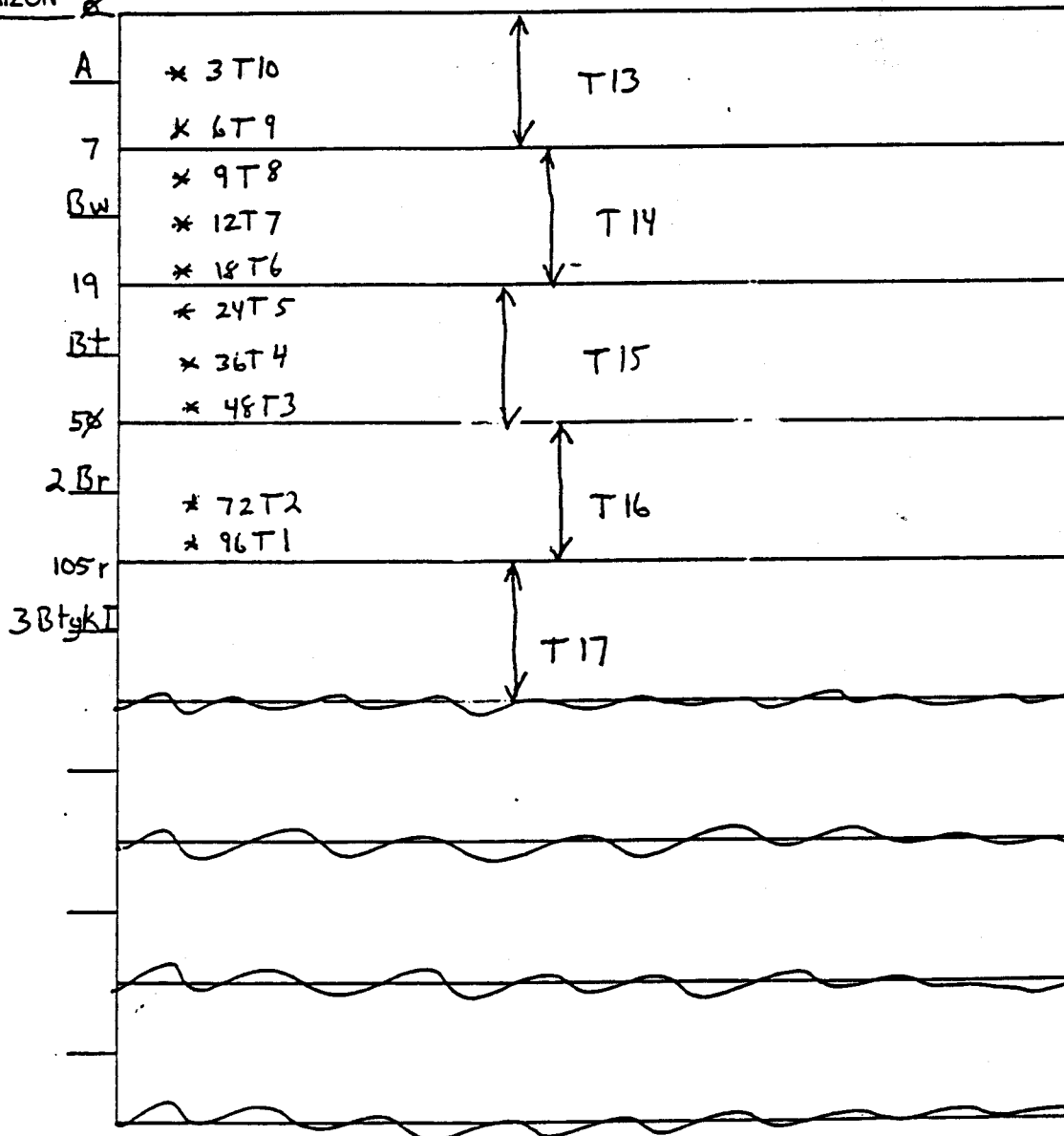
ROCKY FLATS FIELD ACTIVITIES REPORT PIT & TRENCH SAMPLING

PROJECT NUMBER 4006
PROJECT NAME 002 Trenches
TRENCH NUMBER TR-2
SAMPLERS RCH, MZL

DATE 7/13 8/10/92

COORDINATES N
E

Depth (in) HORIZON



T1= 1130	T9= 1146	T17= 1520	T25=	T33=	T41=
T2= 1132	T10= 1148	T18=	T26=	T34=	T42=
T3= 1134	T11= 1240	T19=	T27=	T35=	T43=
T4= 1136	T12= 1350	T20=	T28=	T36=	T44=
T5= 1138	T13= 1400	T21=	T29=	T37=	T45=
T6= 1140	T14= 1410	T22=	T30=	T38=	T46=
T7= 1142	T15= 1422	T23=	T31=	T39=	T47=
T8= 1144	T16= 1430	T24=	T32=	T40=	T48=

Radiation Samples

Sample #	Depth	Horizon	Time	Comments
393, 394	46	2 Br	113E	Radiation slide (RB, RC) w/ Rad Screen
395	72	2 Br	1132	
396	48	BT	1124	
397, 398	36	BT	1136	
399	24	BT	1138	
400	18	BW	1140	
401	12	BW	1142	
402	9	BW	1144	
403	6	A	1146	
404	3	A	1148	
405	—	—	1240	Rinse
Sample # 394 and 398 Duplicates				

Trench Samples

Sample #	Depth	Horizon	Time	Comments
410, 411, 412	10.5 +			ENVL SAMPLE SET "SEE BELOW"
↓	↓			NOTE: SAMPLE # 411 and 412 EXCLUDED ONLY #1 and #3 below
409	50-105			ENVL SET
↓	↓			
408	19-50			FULL SET
↓	↓			
407	7-19			FULL SET
↓	↓			
406	0-7			FULL SET
↓	↓			
FULL SET				1. Geo Soil parameters 2. particle size for Radiation slide 3. Clay minerals 4. Specific Surface 5. Bulk density 6. Soil moisture 7. macropore 8. Sequential extraction 9. Rad screen

SOIL PROFILE DESCRIPTION FORM

Project Name: 002 TRENCHES
 Date: 8/10/92 Stop No: TRENCH # X-2
 Survey Crew Members: Row C. Holmes
 Soil Type: _____
 Classification: _____
 Location: _____ Elevation (Ft): _____
 Aspect: Southeast Slope (%): _____ Slope Position: Crack Slope
 Parent Material: claystone and sandstone
 Drainage: poor, well drained Veg. Community: _____
 Veg. Species and % Comp.: _____

Horizon	Depth	Boundary	Color D or M	Coarse Fragment	Texture	Structure	Consistency	Reaction	Roots/ Pores
A	0-7	Gw	10YR 4-2	5-10 %	loam	1M 5BK	Loose	NONE	3A-FIN
B ₁ W	7-19	CW	10YR 3-2	35-50 %	sandy loam	1G-2M 1M 6R	Loose	NONE	1M-C EX
B ₂ BT	19-50	CI	10YR 5-6 10YR 5-3	LS %	clay	3CABK	very hard	NONE	V2 VLOS -FEX
2B ₁	50-105	AI	7.5YR 6-8 10YR 7-8 2.5Y 1-1	LS %	sandy clay	1-2M-CABK 1M-C EX	soft	NONE	F1 M-COS EX
3BTgKI	105 plus		2.5Y 5-0	LS %	clay	2-3M-CABK	soft	very strong	V2 FEX

/2-3F-MI
 /2-3F-MI
 /2MEXI
 /3MF-MEXI
 /1F-MEXI

Comments: groundwater observed @ 135 cm; ant nests observed in top 12 cm; major lateral discontinuity observed at 10 1/2 feet from west corner of pit; manganese oxide and iron oxide - numerous, observed in 2B₁ horizon.
 BT- organic matter translocation observed along old roots and other cracks.
 2B₁: numerous mottles observed.

① probably color when dry ~~not~~ ^{RCH} ~~most~~ ^{roots}

Completed By: Row C. Holmes

Row C. Holmes

8/10/92

Print Name

Signature

Date

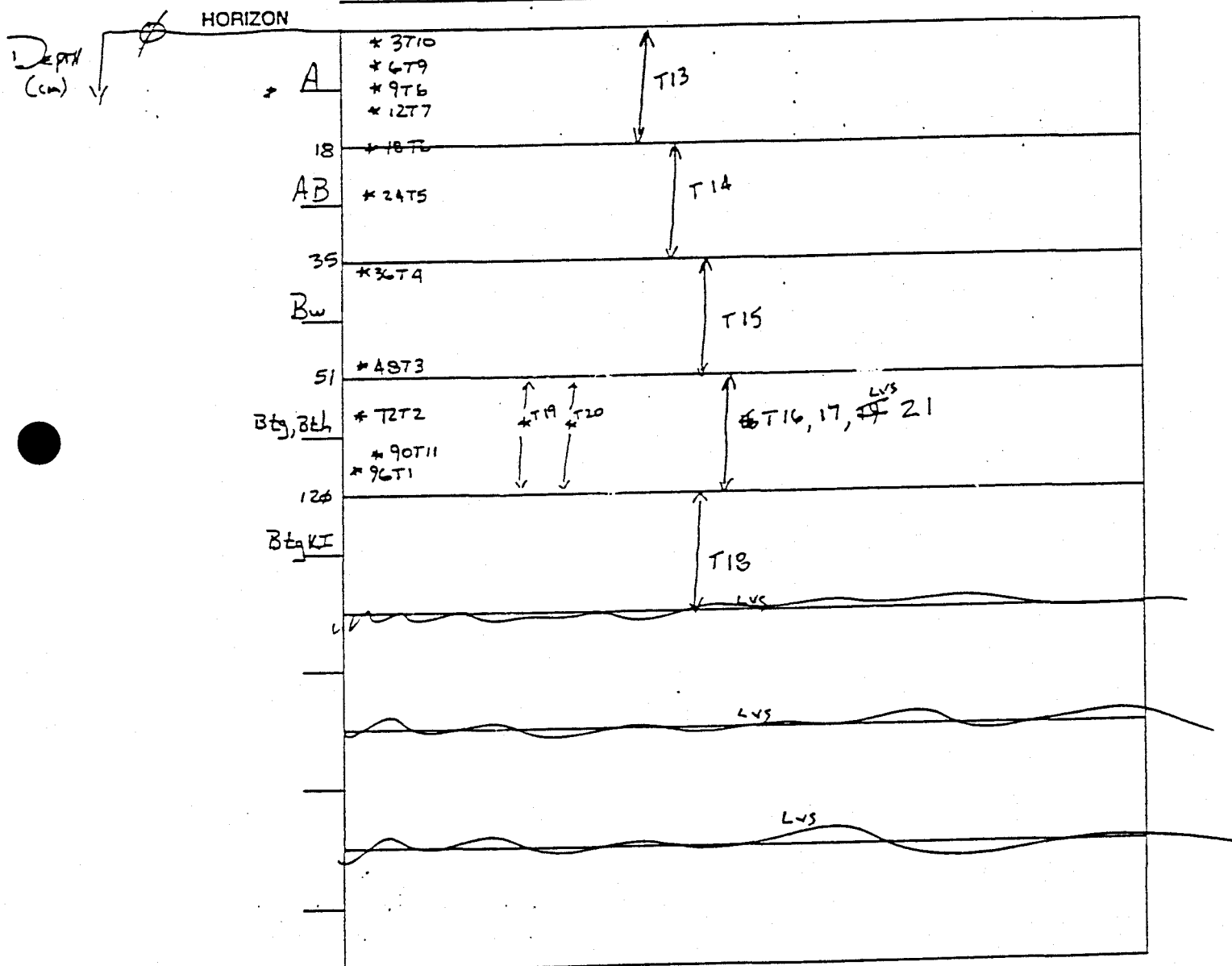
Subcontractor: _____

ROCKY FLATS FIELD ACTIVITIES REPORT PIT & TRENCH SAMPLING

PROJECT NUMBER A006
PROJECT NAME OU2 TRENCHES
TRENCH NUMBER TR-3
SAMPLERS RCH MEL

DATE 7/27/92, 7/29/92

COORDINATES N _____
E _____



T1= 1231
T2= 1232
T3= 1234
T4= 1240
T5= 1249
T6= 1308
T7= 1310
T8= 1312

T9= 1313
T10= 1314
T11= 1320
T12= 1334
T13= 1346
T14= 1355
T15= 1410
T16= 1427

T17= 1636
T18= 1655
T19= 1240
T20= 1244
T21= 1300
T22= 1250
T23=
T24=

T25=
T26=
T27=
T28=
T29=
T30=
T31=
T32=

T33=
T34=
T35=
T36=
T37=
T38=
T39=
T40=

T41=
T42=
T43=
T44=
T45=
T46=
T47=
T48=

TRxxxxxwcu2
Radiation Samples

Sample #	Depth(cm)	Horizon	Time	Comments
00372	96	Btg	1231	RAD w/ SCREEN 7/27/92
373	72	Btg	1232	
374	48	Btg	1236	
375	36	Bw	1240	
376	24	AB	1249	
377	18	AB/A	1308	
378	12	A	1310	
379	9	A	1312	
380	6	A	1313	
381	3	A	1314	7/27/92
389	51-120	Bth	7/29/92 1240	7/29/92
390	51-120	Bth	" 1344	
392	—	—	" 1250	RWS 7/29/92

382 90 Beg 1320
385 90 Beg 1446 RAD w/ SCREEN 7/27/92

Sample #	Depth(cm)	Horizon	Time	Comments
383	0-19	A	1535	FULL SUITE
384	19-35	AB	1550	
385	35-51	Bw	1610	
386	51-120	Btg (LH)	1625	
387	120+	Btg KI	1655	
388	51-120	Btg (LH)	1635	FULL SUITE EXCEPT 7
391	51-120	Btg	1300	FULL SUITE EXCEPT A, 7

1. GENERAL SOIL PARAMETERS
2. PARTICLE SIZE FOR ACTINIDES
3. CLAY MINERALS
4. SOIL MOISTURE
5. SPECIFIC SURFACE
6. BULK DENSITY
7. SEQUENTIAL EXTRACTION
8. MACRO PORE

Radiation Samples

Sample #	Depth	Horizon	Time	Comments
393, 394	96	2 Br	1130	Radionuclide (P.B.Rc) w/ Rad Smm
395	72	2 Br	1132	
396	48	Bt	1134	
397, 398	26	Bt	1136	
399	24	Bt	1138	
400	18	Bw	1140	
401	12	Bw	1142	
402	9	Bw	1144	
403	6	A	1146	
404	3	A	1148	
405	—	—	1240	Rinse
Sample # 394 and 398 Duplicates				

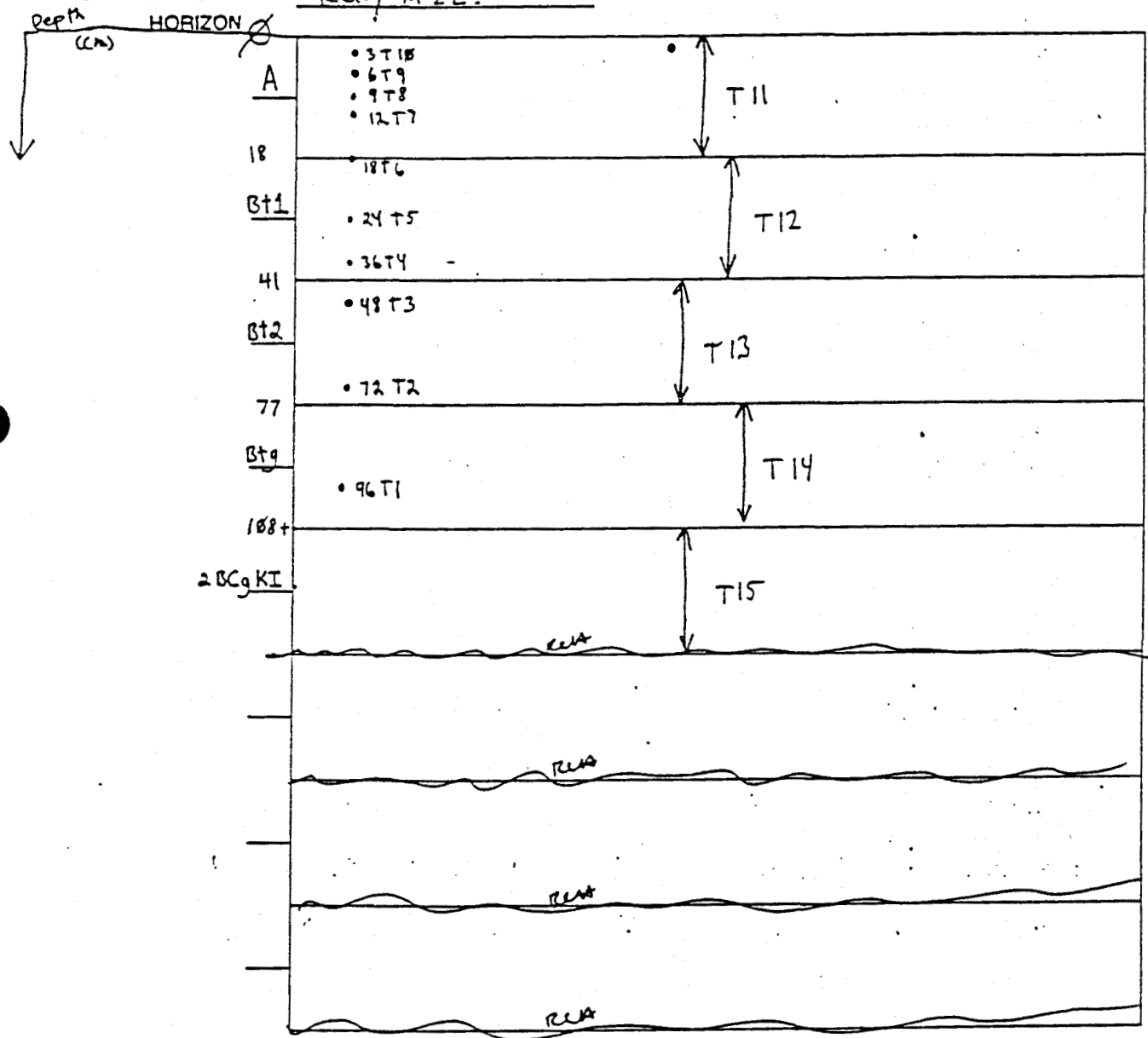
Trench Samples

Sample #	Depth	Horizon	Time	Comments
410, 411, 412	105 +			FULL SAMPLE SET "SEE BELOW"
↓	↓			NOTE: SAMPLE # 411 and 412 EXCLUDED ONLY #1 and #3 below
409	50-105			FULL SET
↓	↓			
408	19-50			FULL SET
↓	↓			
407	7-19			FULL SET
↓	↓			
406	0-7			FULL SET
↓	↓			
FULL SET				<ul style="list-style-type: none"> 1. Geo Soil parameters 2. particle size for Radionuclides 3. clay minerals 4. Specific Surface 5. Bulk density 6. Soil moisture 7. macropore 8. Sequential extraction

ROCKY FLATS FIELD ACTIVITIES REPORT PIT & TRENCH SAMPLING

PROJECT NUMBER 4086
PROJECT NAME 002 trenches
TRENCH NUMBER TR-4
SAMPLERS RCH, MZL.

DATE 8-26-72
COORDINATES N
E



T1= 1210	T9= 1226	T17=	T25=	T33=	T41=
T2= 1212	T10= 1228	T18=	T26=	T34=	T42=
T3= 1214	T11= 1510	T19=	T27=	T35=	T43=
T4= 1216	T12= 1520	T20=	T28=	T36=	T44=
T5= 1218	T13= 1540	T21=	T29=	T37=	T45=
T6= 1220	T14= 1550	T22=	T30=	T38=	T46=
T7= 1222	T15= 0810	T23=	T31=	T39=	T47=
			T32=	T40=	T48=

Radiation Samples

Sample #	Depth(cm)	Horizon	Time	Comments
413	96	BTg	1210	Radioactive (RB, CC) w/ Rad Screen
414	72	BT2	1212	
415	48	BT2	1214	
416	36	BT1	1216	
417	24	BT1	1218	
418	18	BT1	1220	
419	12	A	1222	
420	9	A	1224	
421	6	A	1226	
422	3	A	1228	
423	—	—	1244	Rinsate (422)

Trench Samples

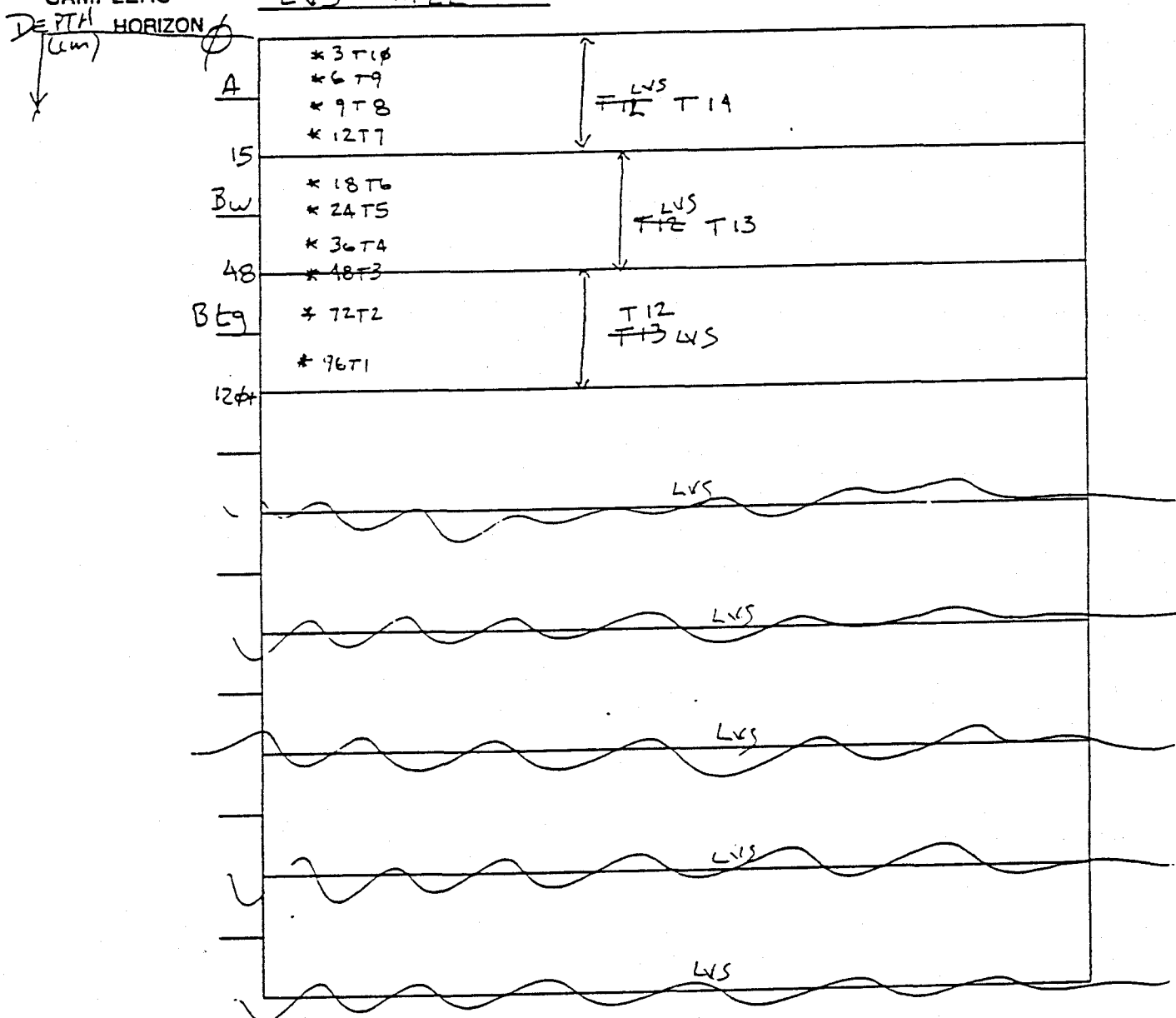
Sample #	Depth	Horizon	Time	Comments
TRENCH 428 WCU2	108 +	"	0810	SAMPLES 1-8 below
↓	↓	↓	↓	NOTE: RAD SCREEN and Gen. Soil Para. Sampled
" 427 "	77-108	"	1550	2. 1600 on 8-25-92, all others 0810 8-20-92
↓	↓	↓	↓	SAMPLES 1-8 below
" 426 "	41-77	"	1540	SAMPLES 1-8 below
↓	↓	↓	↓	
" 425 "	19-41	"	1520	SAMPLES 1-8 below
↓	↓	↓	↓	
" 424 "	0-18	"	1510	SAMPLES 1-8 below
↓	↓	↓	↓	
SPECIAL SAMPLES				
TRENCH 431 WCU2	70-92 (cm)	BT2, BT9	1445	RAD SCREEN and Actinides only
↓	↓	↓	↓	
TRENCH 432 WCU2	41-77	BT2	1540	#1, #3, #4, #7 below
↓	↓	↓	↓	
Full Set				
1. General Soil parameters				
2. Particle Size per Actinides				
3. Specific Surface Area				
4. Clay Minerals				
5. Soil Moisture				
6. Bulk density				
7. Sequential Extraction				
8. RAD SCREEN				

ROCKY FLATS FIELD ACTIVITIES REPORT PIT & TRENCH SAMPLING

PROJECT NUMBER 4006
PROJECT NAME OUT TRENCHES
TRENCH NUMBER T12-5
SAMPLERS LVS mZL

DATE 7/13/92

COORDINATES N
E



T1= 1424	T9= 1514	T17=	T25=	T33=	T41=
T2= 1433	T10= 1510	T18=	T26=	T34=	T42=
T3= 1440	T11= 1540	T19=	T27=	T35=	T43=
T4= 1444	T12= 0815	T20=	T28=	T36=	T44=
T5= 1453	T13= 0830	T21=	T29=	T37=	T45=
T6= 1500	T14= 0845	T22=	T30=	T38=	T46=
T7= 1520	T15=	T23=	T31=	T39=	T47=
T8= 1519	T16=	T24=	T32=	T40=	T48=

TR200XXXWCUZ

Radiation Samples

Sample #	Depth(cm)	Horizon	Time	Comments
358	96	Btg	1424	FE RADIONUCLIDE (RB, RC) w/ RAD SCREEN
359	72	Btg	1433	
360	48	Btg/Bw	1440	
361	36	Bw	1444	
362	24	Bw	1453	
363	18	Bw	1500	
364	12	A	1520	
365	9	A	1519	
366	6	A	1514	
367	3	A	1510	
368			1540	RINSTATE (367)

Trench Samples

Sample #	Depth(cm)	Horizon	Time	Comments
370 ³⁶⁹	48-120+	Btg	0815	1. SOIL MOISTURE 2. GENERAL SOIL PARAMETERS 3. PARTICLE SIZE FOR ALTIMETERS 4. CLAY MINERALS 5. SPECIFIC SURFACE 6. BULK DENSITY 7. SEQUENTIAL EXTRACTION
370	15-48	Bw	0830	1. 2. 3. 4. 5. 6. 7.
371	0-15	A	0845	1. 2. 3. 4. 5. 6. 7.

Appendix IV

Pre-Installation Calibration of Load Cells

LOAD CELL CALIBRATION

October 5, 1992

EDWARD DAL LAGO

OGDEN ENVIRONMENTAL

OU2 SURFICIAL SOIL SAMPLING PROJECT

ROCKY FLATS PLANT, GOLDEN, COLORADO

FILENAME: 10_5LOAD.XLS

LOAD CELL MODEL: INTERFACE, INC. SPI-7.5

LOAD NO.	OBJECT	WEIGHT (gm)	LOAD (gm)
	Platform	47.87	
1	#1	68.98	116.85
2	#2	220.73	268.6
3	#3	312.68	360.55
4	#4	529.52	577.39
5	#5	608.04	655.91
6	#5+#2	828.77	876.64
7	#5+#3	920.72	968.59
8	#5+#4	1137.56	1185.43

LOAD(gm) = Weight of Object (gm) + Weight of Platform (gm)

CALCULATIONS:

MAX OUTPUT (mV) = BATTERY VOLTAGE (V) X RATED OUTPUT (mV)

OUTPUT (mV) = VOLTAGE MEASURED ACROSS LOAD CELL

VOLTAGE (mV) = OUTPUT (mV) - NO LOAD (mV)

CALIBRATED WEIGHT (mV) = MAX OUTPUT(mV) x VOLTAGE (mV)

EXAMPLE: (40.37 mV/3.4 kg) x 47.87gm = 0.57 mV

SERIAL NO:

C16353

RATED OUTPUT, COMPRESSION (mV/V)=

3.127 @ 3.4 kg AND 10 VOLTS

BATTERY VOLTAGE (V)=

12.91

MAX OUTPUT (mV)=

40.37 @ 3.4 kg CALIBRATED WEIGHT

OBJECT	LOAD (gm)	OUTPUT (mV)	VOLTAGE (mV)	CALIBRATED WEIGHT (mV)
No Load	0	0.4	0	0.00
Platform	47.87	0.9	0.5	0.57
1	116.85	1.7	1.3	1.39
2	268.6	3.5	3.1	3.19
3	360.55	4.6	4.2	4.28
4	577.39	7.2	6.8	6.85
5	655.91	8.1	7.7	7.78
6	876.64	10.7	10.3	10.40
7	968.59	11.8	11.4	11.49
8	1185.43	14.3	13.9	14.07

SERIAL NO:

C16355

RATED OUTPUT, COMPRESSION (mV/V)=

3.133 @ 3.4 kg AND 10 VOLTS

BATTERY VOLTAGE (V)=

12.91

MAX OUTPUT (mV)=

40.45 @ 3.4 kg CALIBRATED WEIGHT

OBJECT	LOAD (gm)	OUTPUT (mV)	VOLTAGE (mV)	CALIBRATED WEIGHT (mV)
No Load	0	0.5	0	0.00
Platform	47.87	1.2	0.7	0.57
1	116.85	2	1.5	1.39
2	268.6	3.8	3.3	3.19
3	360.55	4.9	4.4	4.29
4	577.39	7.5	7	6.87
5	655.91	8.4	7.9	7.80
6	876.64	11	10.5	10.42
7	968.59	12.1	11.6	11.52
8	1185.43	14.7	14.2	14.10

SERIAL NO:

C16359

RATED OUTPUT, COMPRESSION (mV/V)=

3.128 @ 3.4 kg AND 10 VOLTS

BATTERY VOLTAGE (V)=

12.92

MAX OUTPUT (mV)=

40.41 @ 3.4 kg CALIBRATED WEIGHT

OBJECT	LOAD (gm)	OUTPUT (mV)	VOLTAGE (mV)	CALIBRATED WEIGHT (mV)
No Load	0	0	0	0.00
Platform	47.87	0.6	0.6	0.57
1	116.85	1.4	1.4	1.39
2	268.6	3.2	3.2	3.19
3	360.55	4.3	4.3	4.28
4	577.39	6.8	6.8	6.86
5	655.91	7.8	7.8	7.79
6	876.64	10.4	10.4	10.41
7	968.59	11.5	11.5	11.51
8	1185.43	14.1	14.1	14.08

SERIAL NO:

C16360

RATED OUTPUT, COMPRESSION (mV/V)=

3.242 @ 3.4 kg AND 10 VOLTS

BATTERY VOLTAGE (V)=

12.93

MAX OUTPUT (mV)=

41.92 @ 3.4 kg CALIBRATED WEIGHT

OBJECT	LOAD (gm)	OUTPUT (mV)	VOLTAGE (mV)	CALIBRATED WEIGHT (mV)
No Load	0	0.2	0	0.00
Platform	47.87	0.8	0.6	0.59
1	116.85	1.6	1.4	1.44
2	268.6	3.5	3.3	3.31
3	360.55	4.6	4.4	4.44
4	577.39	7.3	7.1	7.11
5	655.91	8.2	8	8.08
6	876.64	10.9	10.7	10.80
7	968.59	12.1	11.9	11.94
8	1185.43	14.7	14.5	14.61

SERIAL NO:

C16364

RATED OUTPUT, COMPRESSION (mV/V)=

3.163 @ 3.4 kg AND 10 VOLTS

BATTERY VOLTAGE (V)=

12.92

MAX OUTPUT (mV)=

40.87 @ 3.4 kg CALIBRATED WEIGHT

OBJECT	LOAD (gm)	OUTPUT (mV)	VOLTAGE (mV)	CALIBRATED WEIGHT (mV)
No Load	0	0.2	0	0.00
Platform	47.87	0.8	0.6	0.58
1	116.85	1.6	1.4	1.40
2	268.6	3.4	3.2	3.23
3	360.55	4.5	4.3	4.33
4	577.39	7.1	6.9	6.94
5	655.91	8.1	7.9	7.88
6	876.64	10.7	10.5	10.53
7	968.59	11.8	11.6	11.64
8	1185.43	14.4	14.2	14.24

SERIAL NO:

C16373

RATED OUTPUT, COMPRESSION (mV/V)=

3.106 @ 3.4 kg AND 10 VOLTS

BATTERY VOLTAGE (V)=

12.92

MAX OUTPUT (mV)=

40.13 @ 3.4 kg CALIBRATED WEIGHT

OBJECT	LOAD (gm)	OUTPUT (mV)	VOLTAGE (mV)	CALIBRATED WEIGHT (mV)
No Load	0	0	0	0.00
Platform	47.87	0.6	0.6	0.58
1	116.85	1.3	1.3	1.40
2	268.6	3.1	3.1	3.23
3	360.55	4.2	4.2	4.33
4	577.39	6.8	6.8	6.94
5	655.91	7.7	7.7	7.88
6	876.64	10.3	10.3	10.53
7	968.59	11.4	11.4	11.64
8	1185.43	13.9	13.9	14.24

SERIAL NO:

C16374

RATED OUTPUT, COMPRESSION (mV/V)=

3.114 @ 3.4 kg AND 10 VOLTS

BATTERY VOLTAGE (V)=

12.92

MAX OUTPUT (mV)=

40.23 @ 3.4 kg CALIBRATED WEIGHT

OBJECT	LOAD (gm)	OUTPUT (mV)	VOLTAGE (mV)	CALIBRATED WEIGHT (mV)
No Load	0	0	0	0.00
Platform	47.87	0.5	0.5	0.57
1	116.85	1.3	1.3	1.38
2	268.6	3.1	3.1	3.18
3	360.55	4.1	4.1	4.26
4	577.39	6.7	6.7	6.83
5	655.91	7.6	7.6	7.76
6	876.64	10.2	10.2	10.37
7	968.59	11.3	11.3	11.45
8	1185.43	13.9	13.9	14.02

SERIAL NO:

C16375

RATED OUTPUT, COMPRESSION (mV/V)=

3.151 @ 3.4 kg AND 10 VOLTS

BATTERY VOLTAGE (V)=

12.92

MAX OUTPUT (mV)=

40.71 @ 3.4 kg CALIBRATED WEIGHT

OBJECT	LOAD (gm)	OUTPUT (mV)	VOLTAGE (mV)	CALIBRATED WEIGHT (mV)
No Load	0	0.2	0	0.00
Platform	47.87	0.8	0.6	0.57
1	116.85	1.6	1.4	1.40
2	268.6	3.4	3.2	3.21
3	360.55	4.5	4.3	4.31
4	577.39	7.1	6.9	6.91
5	655.91	8	7.8	7.85
6	876.64	10.7	10.5	10.49
7	968.59	11.8	11.6	11.59
8	1185.43	14.3	14.1	14.19

SERIAL NO:

C16380

RATED OUTPUT, COMPRESSION (mV/V)=

3.119 @ 3.4 kg AND 10 VOLTS

BATTERY VOLTAGE (V)=

12.89

MAX OUTPUT (mV)=

40.20 @ 3.4 kg CALIBRATED WEIGHT

OBJECT	LOAD (gm)	OUTPUT (mV)	VOLTAGE (mV)	CALIBRATED WEIGHT (mV)
No Load	0	0.2	0	0.00
Platform	47.87	0.8	0.6	0.57
1	116.85	1.6	1.4	1.38
2	268.6	3.4	3.2	3.18
3	360.55	4.5	4.3	4.26
4	577.39	7.1	6.9	6.83
5	655.91	8	7.8	7.76
6	876.64	10.7	10.5	10.37
7	968.59	11.8	11.6	11.45
8	1185.43	14.3	14.1	14.02

SERIAL NO:

C16381

RATED OUTPUT, COMPRESSION (mV/V)=

3.161 @ 3.4 kg AND 10 VOLTS

BATTERY VOLTAGE (V)=

12.9

MAX OUTPUT (mV)=

40.78 @ 3.4 kg CALIBRATED WEIGHT

OBJECT	LOAD (gm)	OUTPUT (mV)	VOLTAGE (mV)	CALIBRATED WEIGHT (mV)
No Load	0	0.9	0	0.00
Platform	47.87	1.5	0.6	0.57
1	116.85	2.3	1.4	1.38
2	268.6	4.1	3.2	3.18
3	360.55	5.2	4.3	4.26
4	577.39	7.8	6.9	6.83
5	655.91	8.7	7.8	7.76
6	876.64	11.4	10.5	10.37
7	968.59	12.5	11.6	11.45
8	1185.43	15.1	14.2	14.02

SERIAL NO:

C16383

RATED OUTPUT, COMPRESSION (mV/V)=

3.162 @ 3.4 kg AND 10 VOLTS

BATTERY VOLTAGE (V)=

12.9

MAX OUTPUT (mV)=

40.79 @ 3.4 kg CALIBRATED WEIGHT

OBJECT	LOAD (gm)	OUTPUT (mV)	VOLTAGE (mV)	CALIBRATED WEIGHT (mV)
No Load	0	-0.1	0	0.00
Platform	47.87	0.5	0.6	0.57
1	116.85	1.3	1.4	1.40
2	268.6	3.1	3.2	3.22
3	360.55	4.2	4.3	4.32
4	577.39	6.8	6.9	6.92
5	655.91	7.7	7.8	7.86
6	876.64	10.4	10.5	10.51
7	968.59	11.4	11.5	11.61
8	1185.43	14	14.1	14.21

SERIAL NO:

C16386

RATED OUTPUT, COMPRESSION (mV/V)=

3.177 @ 3.4 kg AND 10 VOLTS

BATTERY VOLTAGE (V)=

12.9

MAX OUTPUT (mV)=

40.98 @ 3.4 kg CALIBRATED WEIGHT

OBJECT	LOAD (gm)	OUTPUT (mV)	VOLTAGE (mV)	CALIBRATED WEIGHT (mV)
No Load	0	0.1	0	0.00
Platform	47.87	0.7	0.6	0.58
1	116.85	1.4	1.3	1.41
2	268.6	3.3	3.2	3.24
3	360.55	4.4	4.3	4.34
4	577.39	7	6.9	6.96
5	655.91	7.9	7.8	7.90
6	876.64	10.6	10.5	10.56
7	968.59	11.7	11.6	11.67
8	1185.43	14.3	14.2	14.28

SERIAL NO:

C16387

RATED OUTPUT, COMPRESSION (mV/V)=

3.207 @ 3.4 kg AND 10 VOLTS

BATTERY VOLTAGE (V)=

12.9

MAX OUTPUT (mV)=

41.37 @ 3.4 kg CALIBRATED WEIGHT

OBJECT	LOAD (gm)	OUTPUT (mV)	VOLTAGE (mV)	CALIBRATED WEIGHT (mV)
No Load	0	0.5	0	0.00
Platform	47.87	1.1	0.6	0.58
1	116.85	1.9	1.4	1.42
2	268.6	3.8	3.3	3.27
3	360.55	4.9	4.4	4.38
4	577.39	7.5	7	7.02
5	655.91	8.4	7.9	7.98
6	876.64	11.1	10.6	10.66
7	968.59	12.2	11.7	11.78
8	1185.43	14.9	14.4	14.42

SERIAL NO:

C16396

RATED OUTPUT, COMPRESSION (mV/V)=

3.164 @ 3.4 kg AND 10 VOLTS

BATTERY VOLTAGE (V)=

12.89

MAX OUTPUT (mV)=

40.78 @ 3.4 kg CALIBRATED WEIGHT

OBJECT	LOAD (gm)	OUTPUT (mV)	VOLTAGE (mV)	CALIBRATED WEIGHT (mV)
No Load	0	0.2	0	0.00
Platform	47.87	0.8	0.6	0.57
1	116.85	1.6	1.4	1.40
2	268.6	3.4	3.2	3.22
3	360.55	4.5	4.3	4.32
4	577.39	7.1	6.9	6.92
5	655.91	8.1	7.9	7.86
6	876.64	10.7	10.5	10.51
7	968.59	11.8	11.6	11.61
8	1185.43	14.4	14.2	14.21

SERIAL NO:

C16398

RATED OUTPUT, COMPRESSION (mV/V)=

3.16 @ 3.4 kg AND 10 VOLTS

BATTERY VOLTAGE (V)=

12.9

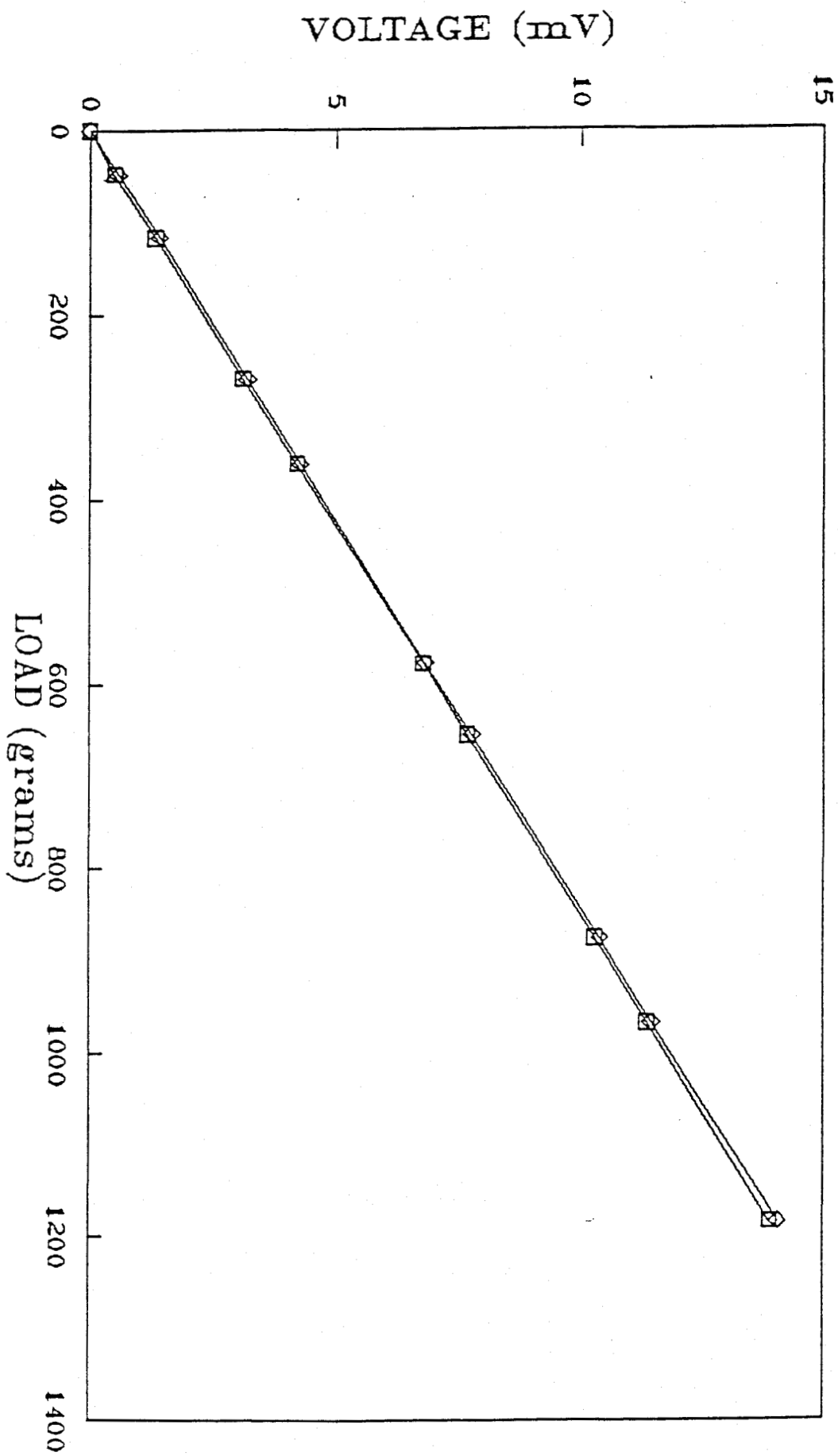
MAX OUTPUT (mV)=

40.76 @ 3.4 kg CALIBRATED WEIGHT

OBJECT	LOAD (gm)	OUTPUT (mV)	VOLTAGE (mV)	CALIBRATED WEIGHT (mV)
No Load	0	0.3	0	0.00
Platform	47.87	1.1	0.8	0.57
1	116.85	1.9	1.6	1.40
2	268.6	3.7	3.4	3.22
3	360.55	4.8	4.5	4.32
4	577.39	7.4	7.1	6.92
5	655.91	8.3	8	7.86
6	876.64	10.8	10.5	10.50
7	968.59	11.9	11.6	11.61
8	1185.43	14.5	14.2	14.20

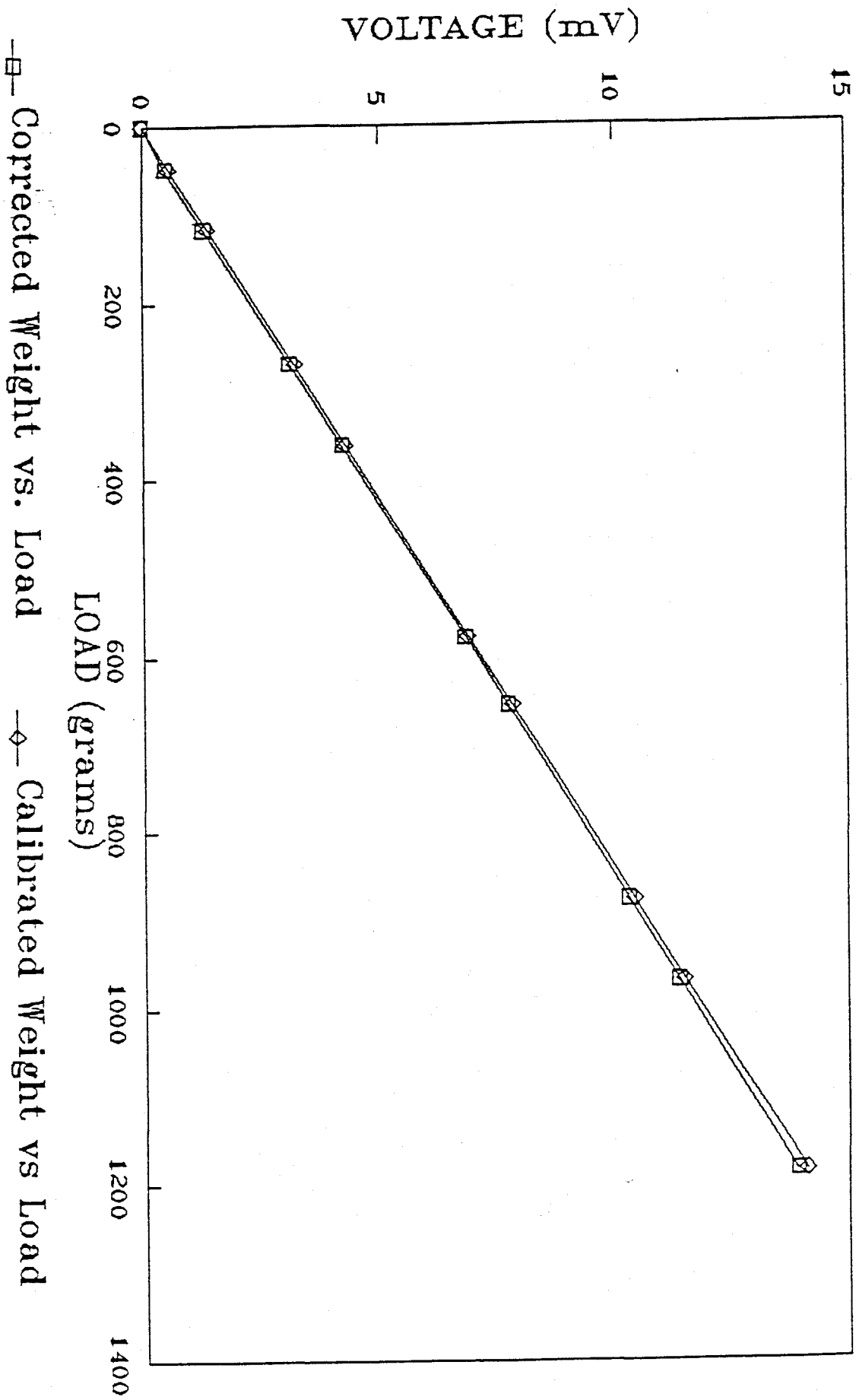
LOAD CELL CALIBRATION

LOAD CELL NO. C16353



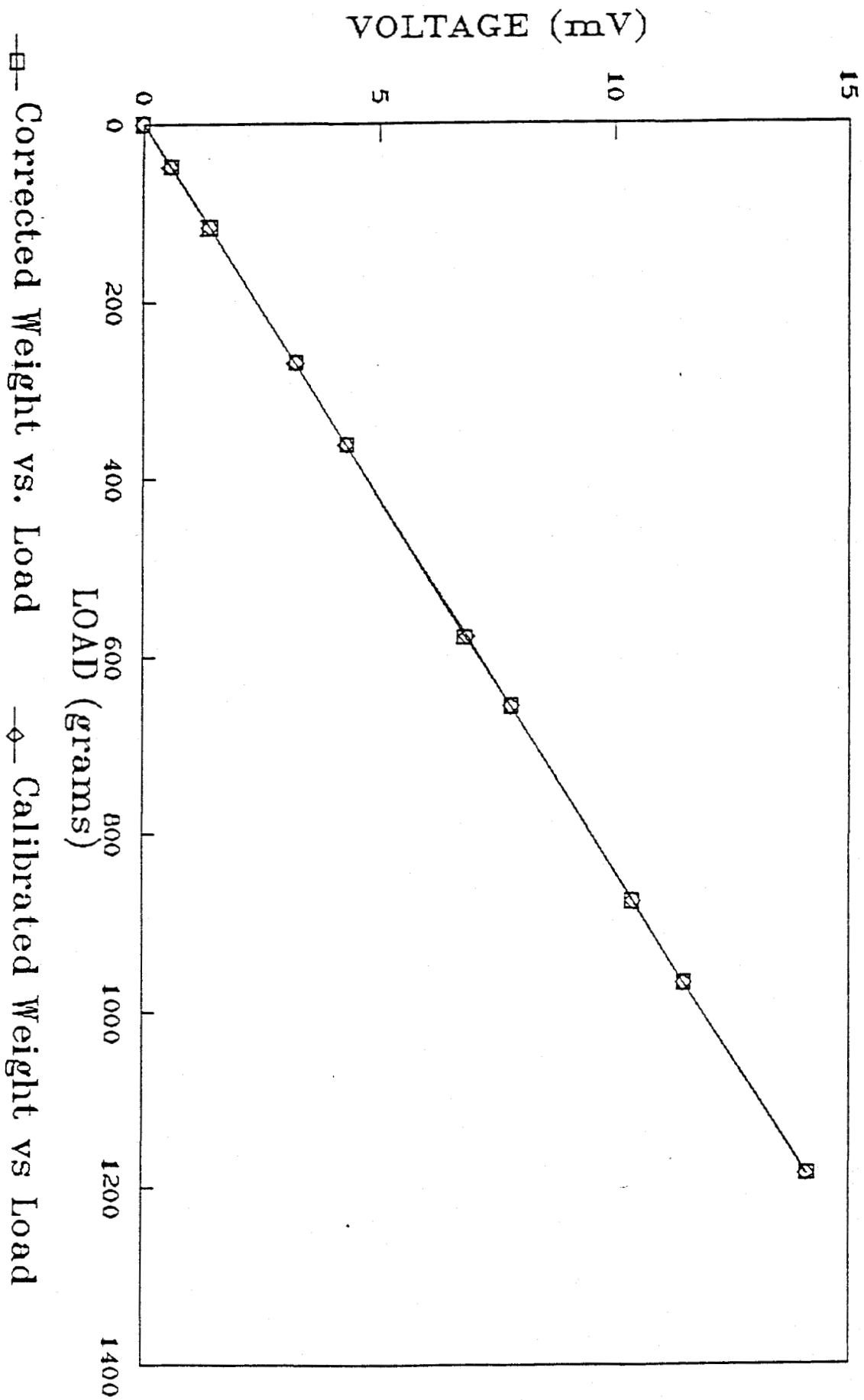
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LOAD CELL NO. C16355



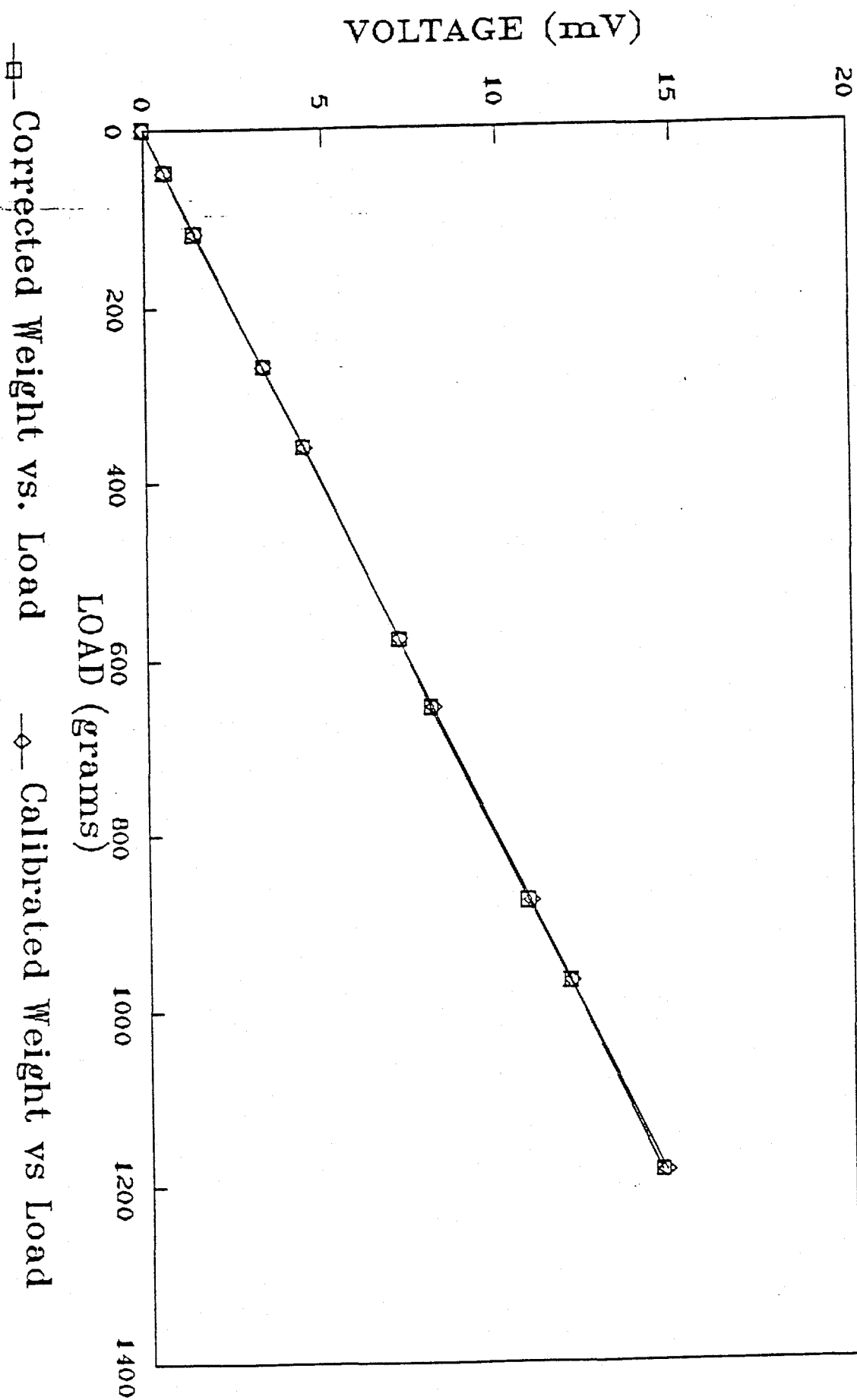
LOAD CELL CALIBRATION

LOAD CELL NO. C16359



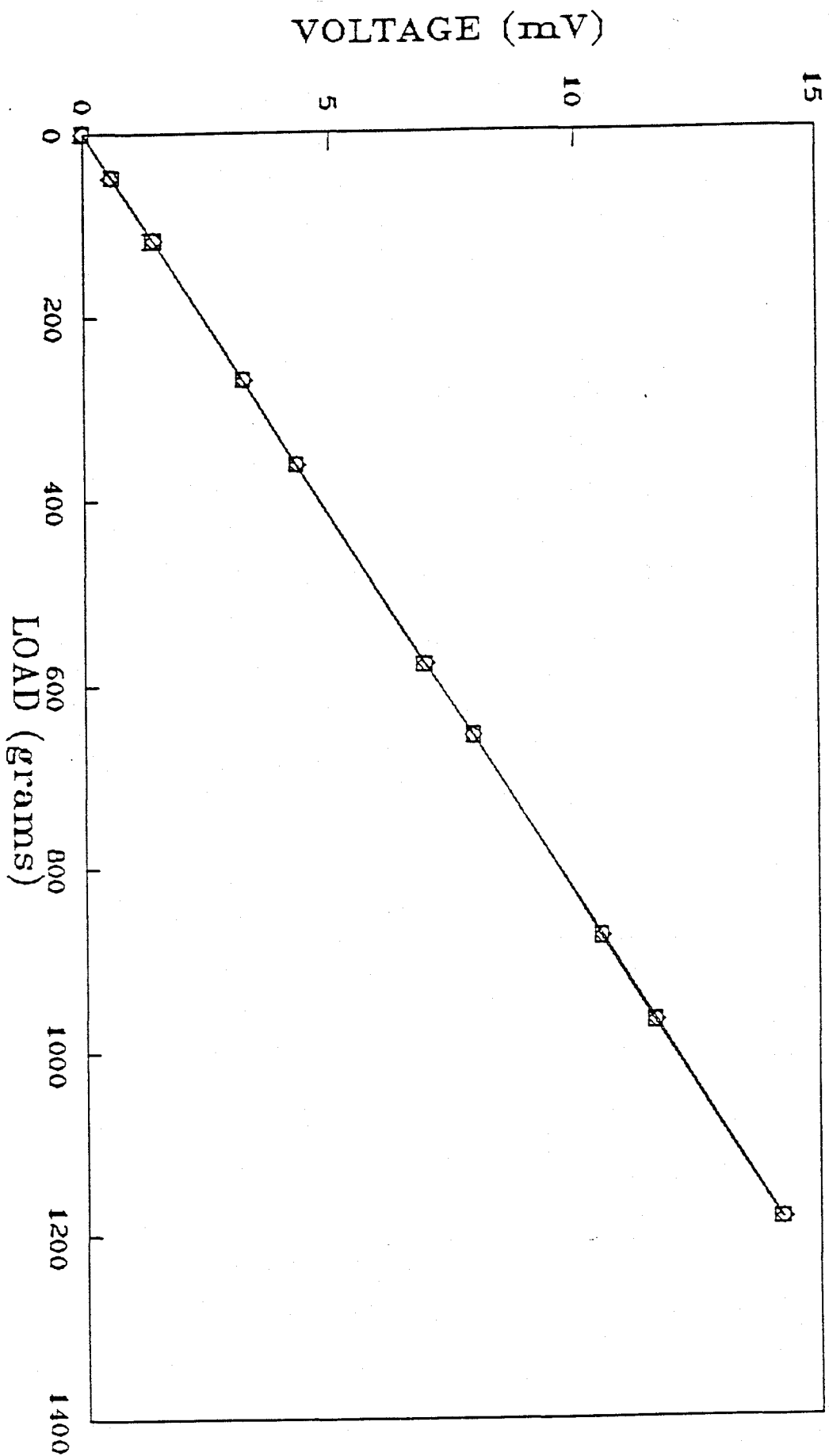
LOAD CELL CALIBRATION

LOAD CELL NO. C16360



LOAD CELL CALIBRATION

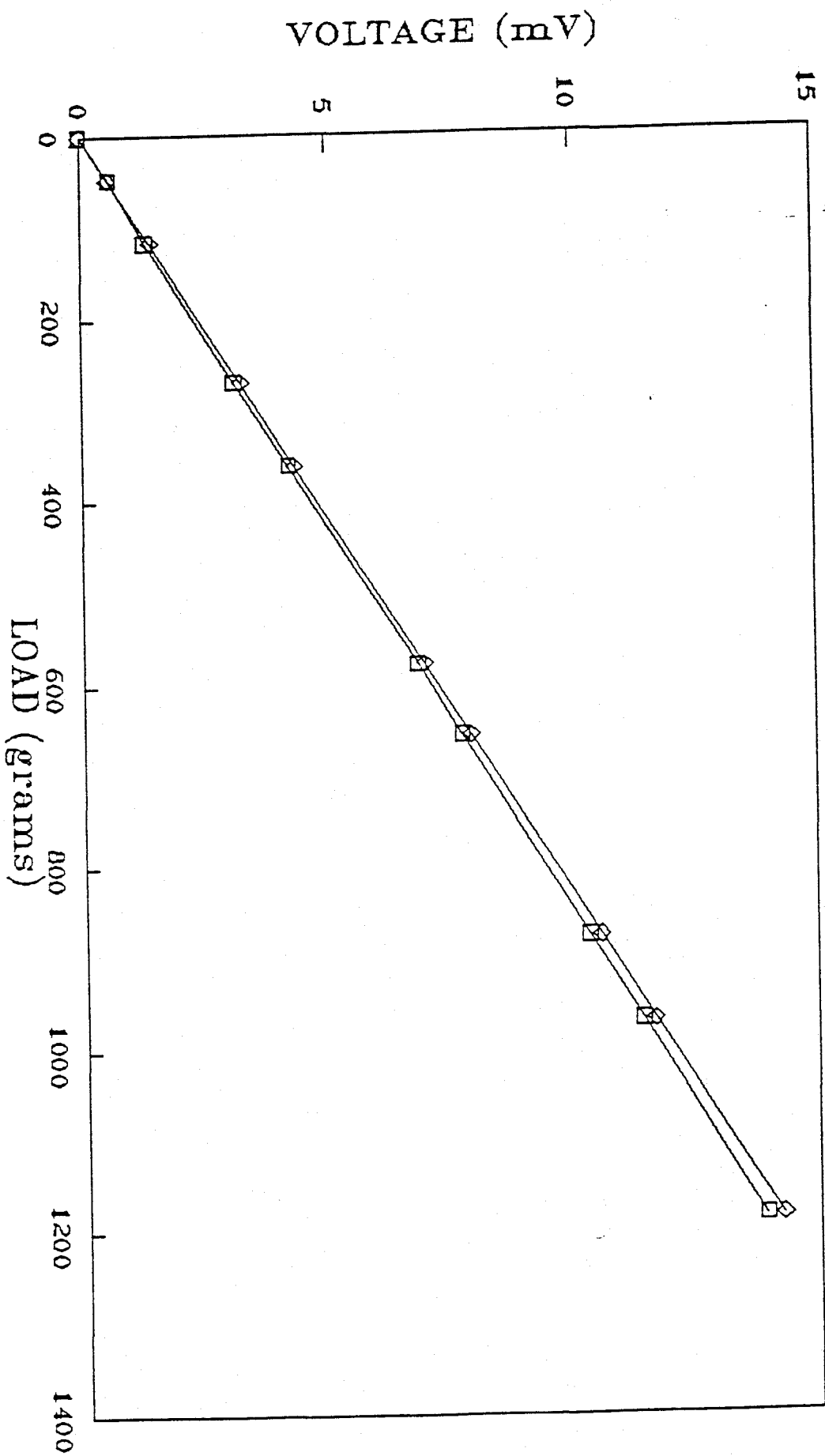
LOAD CELL NO. C16364



—■— Corrected Weight vs. Load —◇— Calibrated Weight vs Load

LOAD CELL CALIBRATION

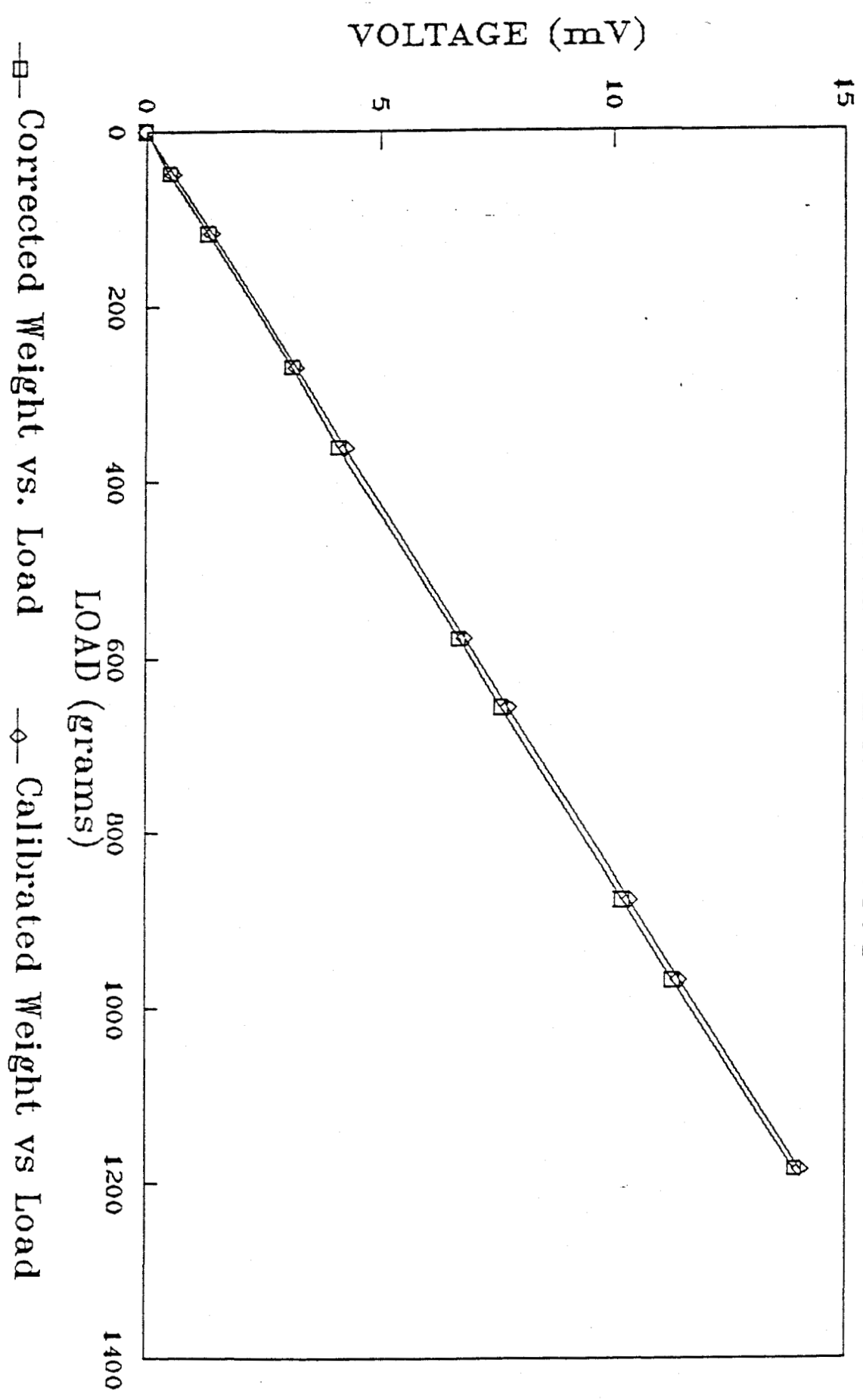
LOAD CELL NO. C16373



—□— Corrected Weight vs. Load —◇— Calibrated Weight vs Load

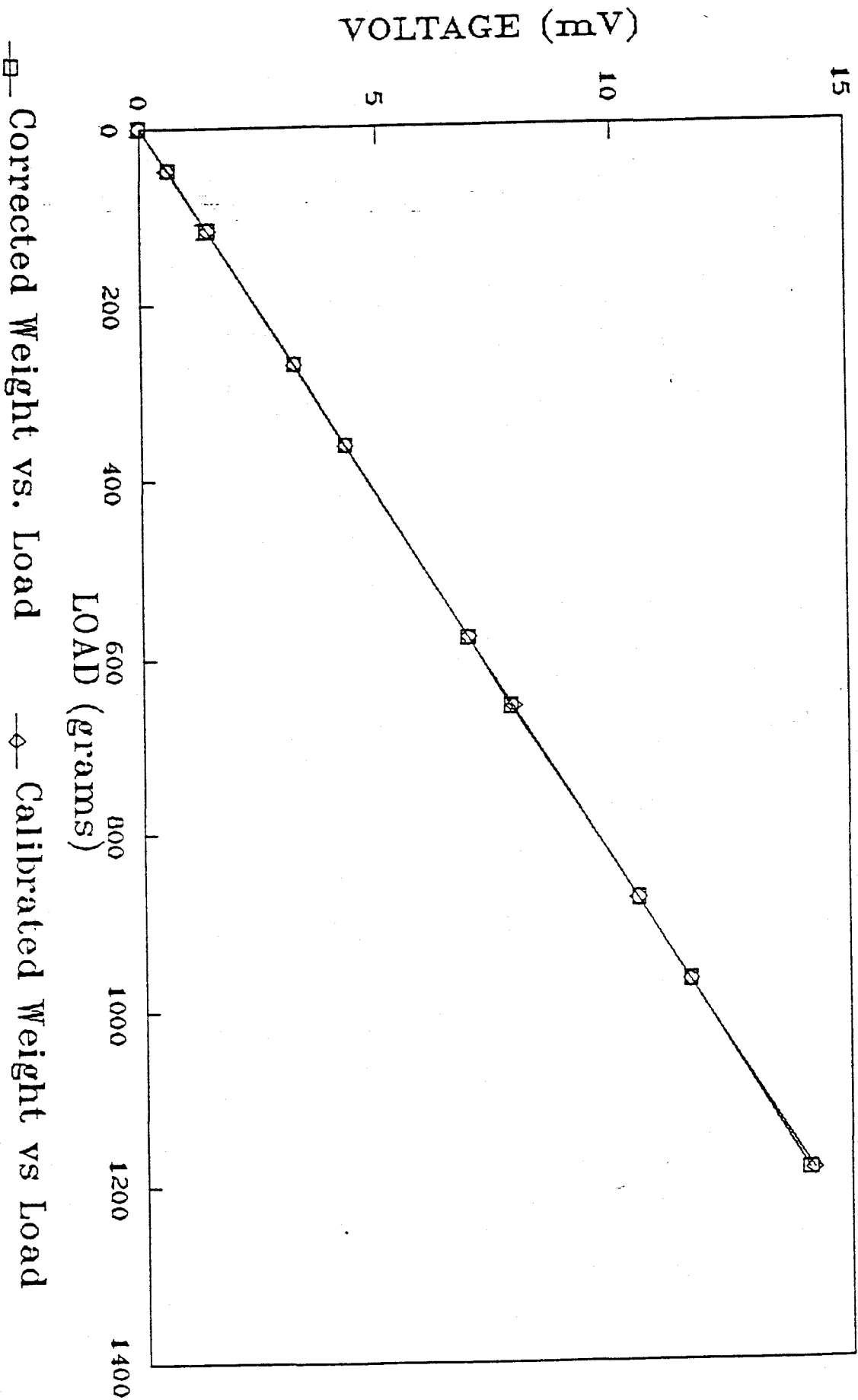
LOAD CELL CALIBRATION

LOAD CELL NO. C16374



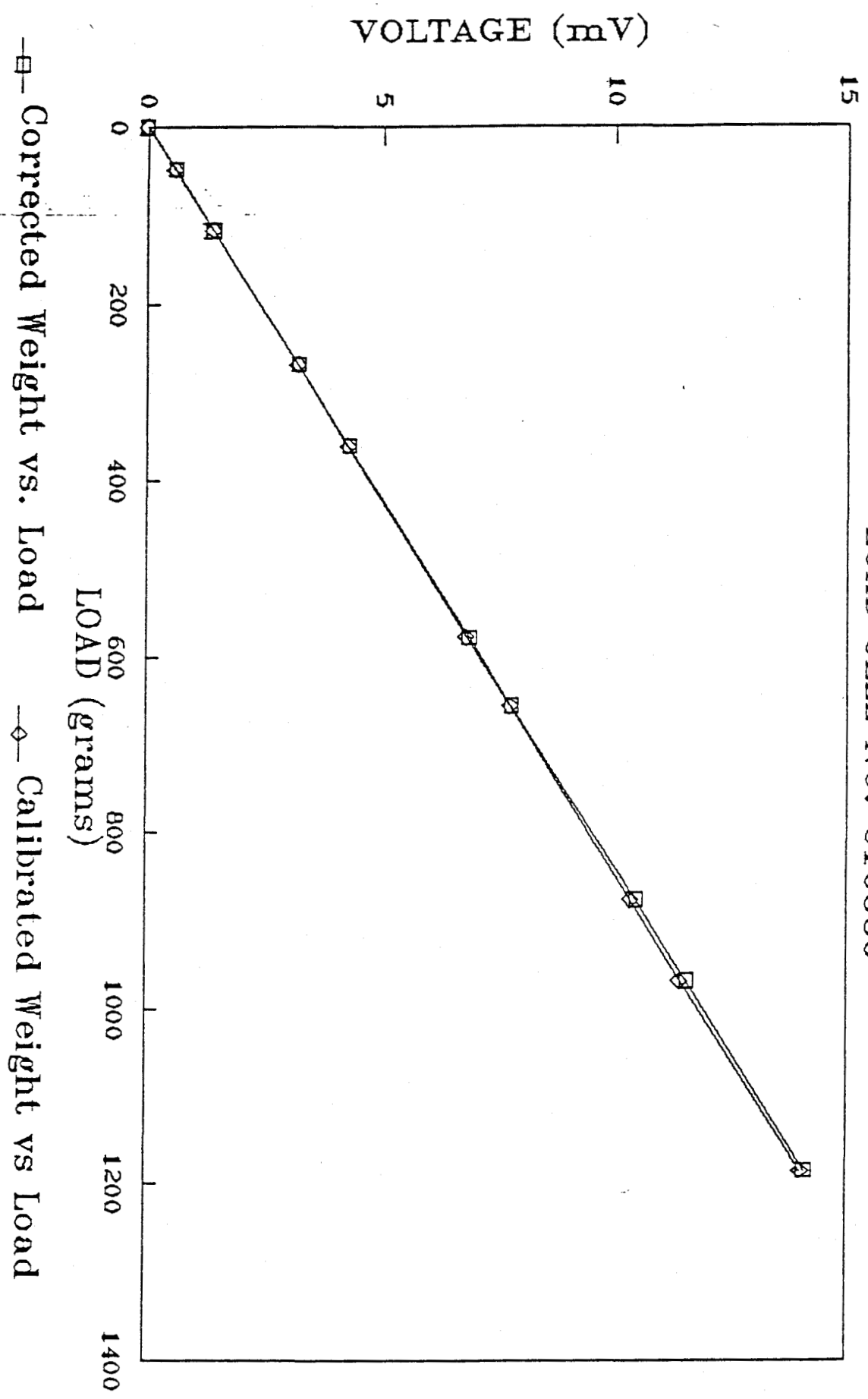
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LOAD CELL NO. C16375



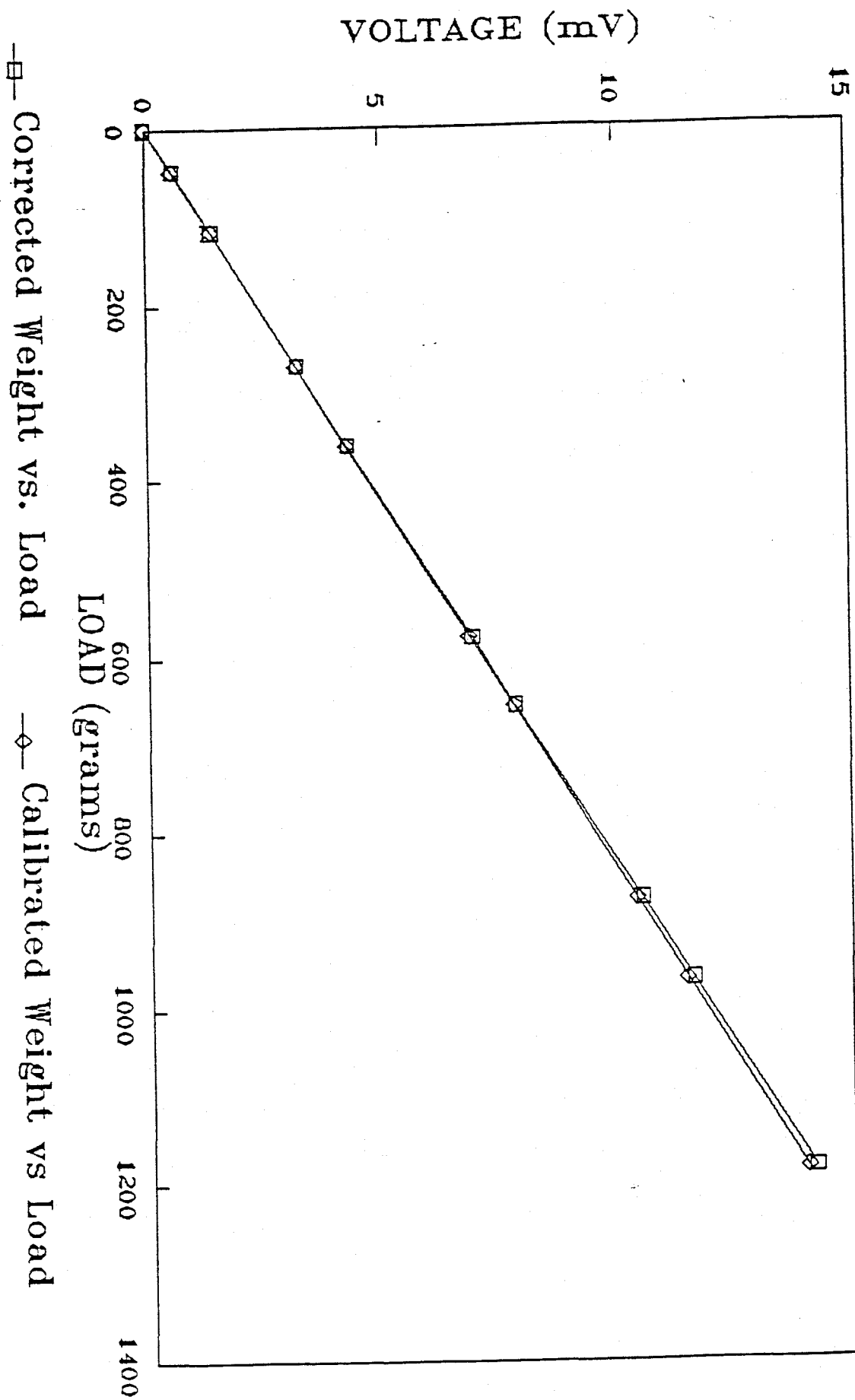
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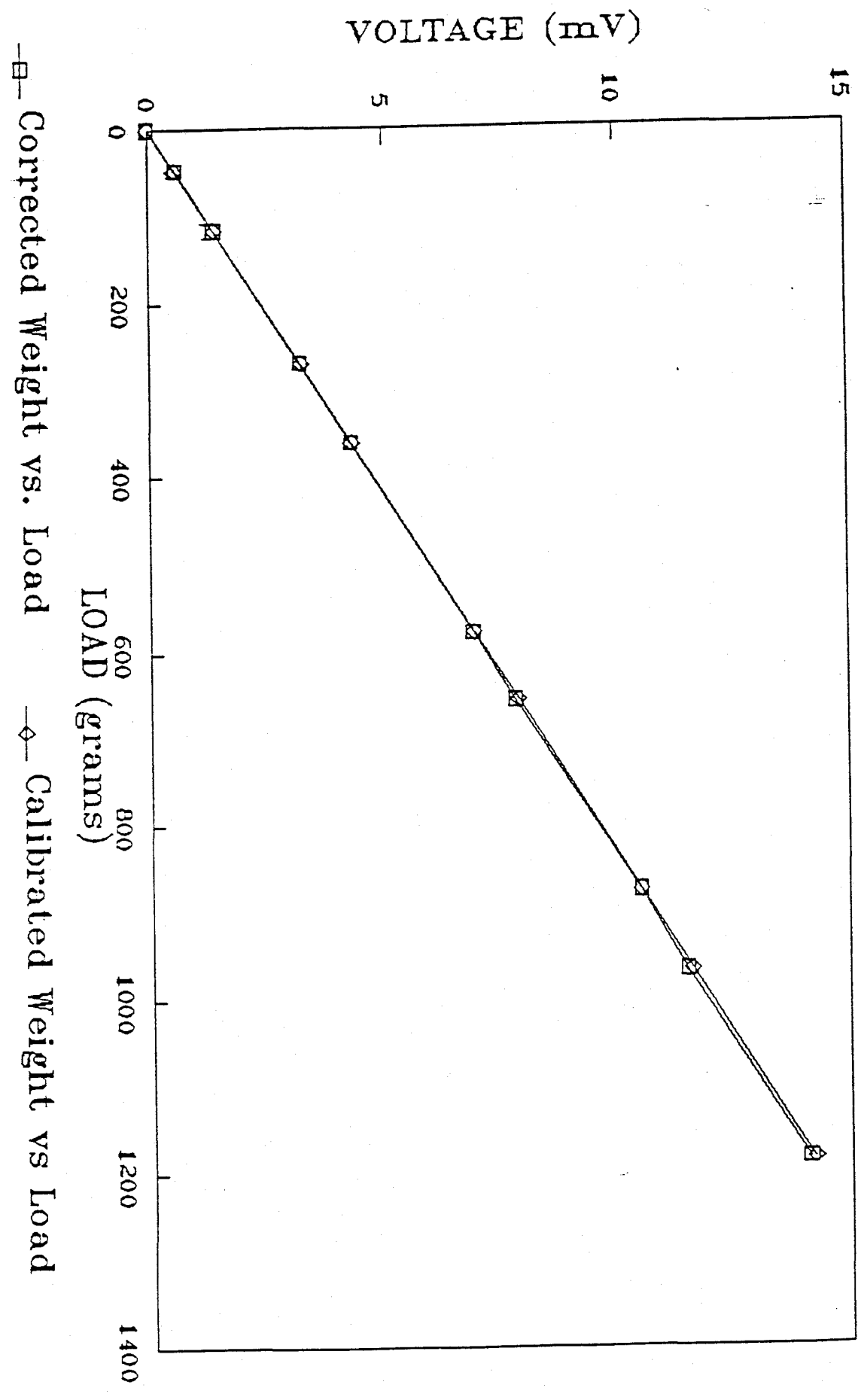
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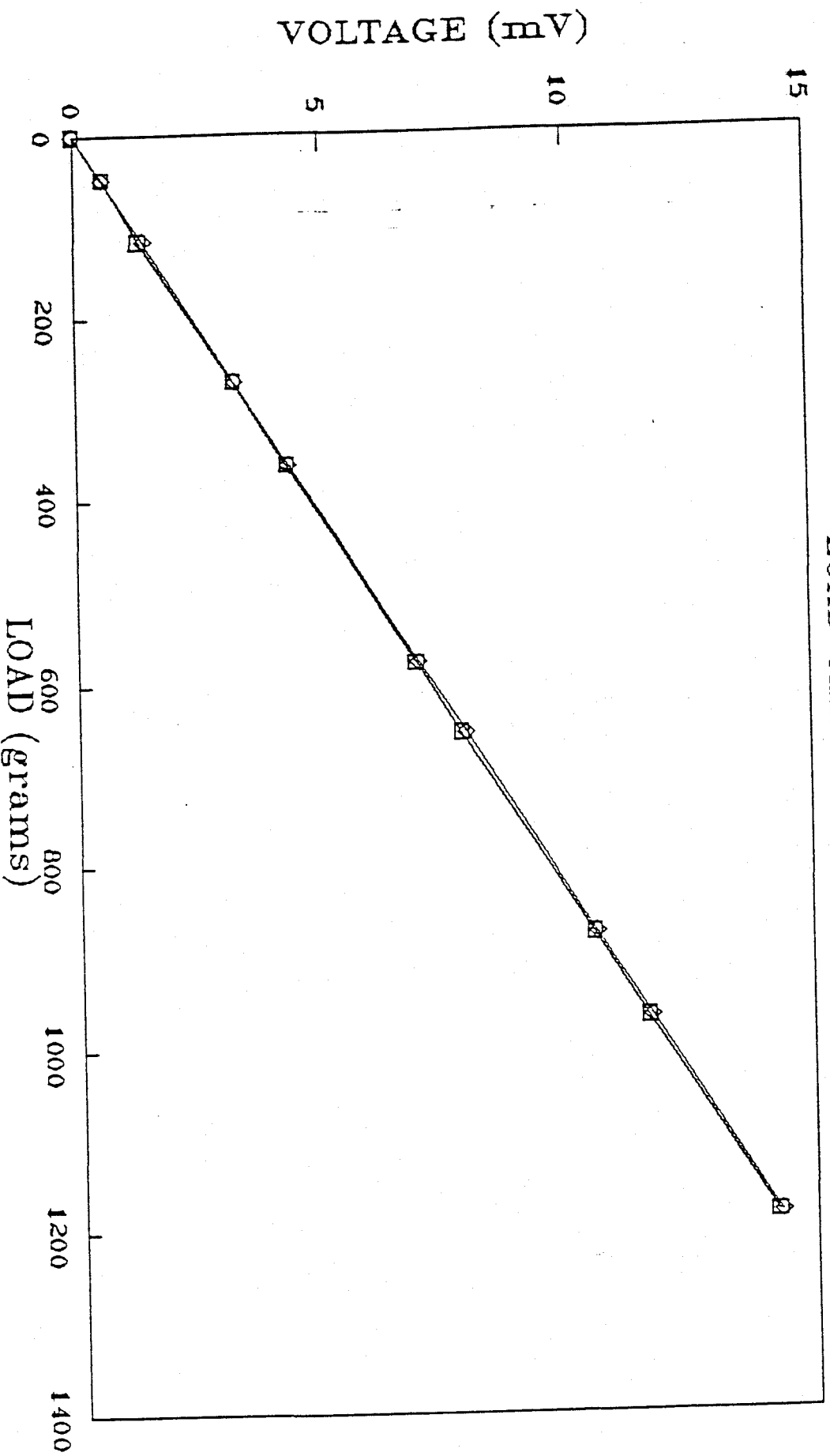
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LOAD CELL NO. C16383



LOAD CELL CALIBRATION

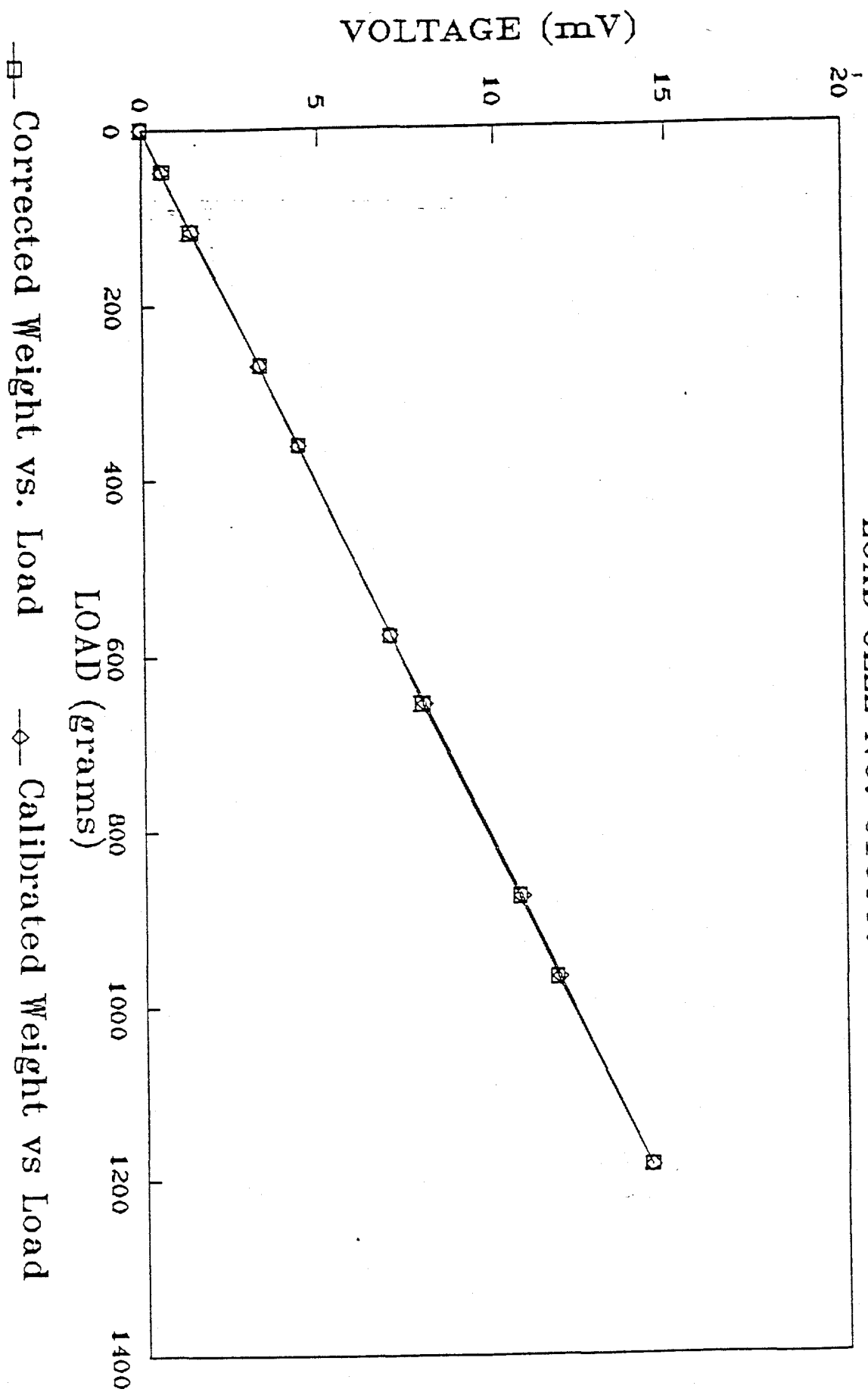
LOAD CELL NO. C16386



—□— Corrected Weight vs. Load —◇— Calibrated Weight vs Load

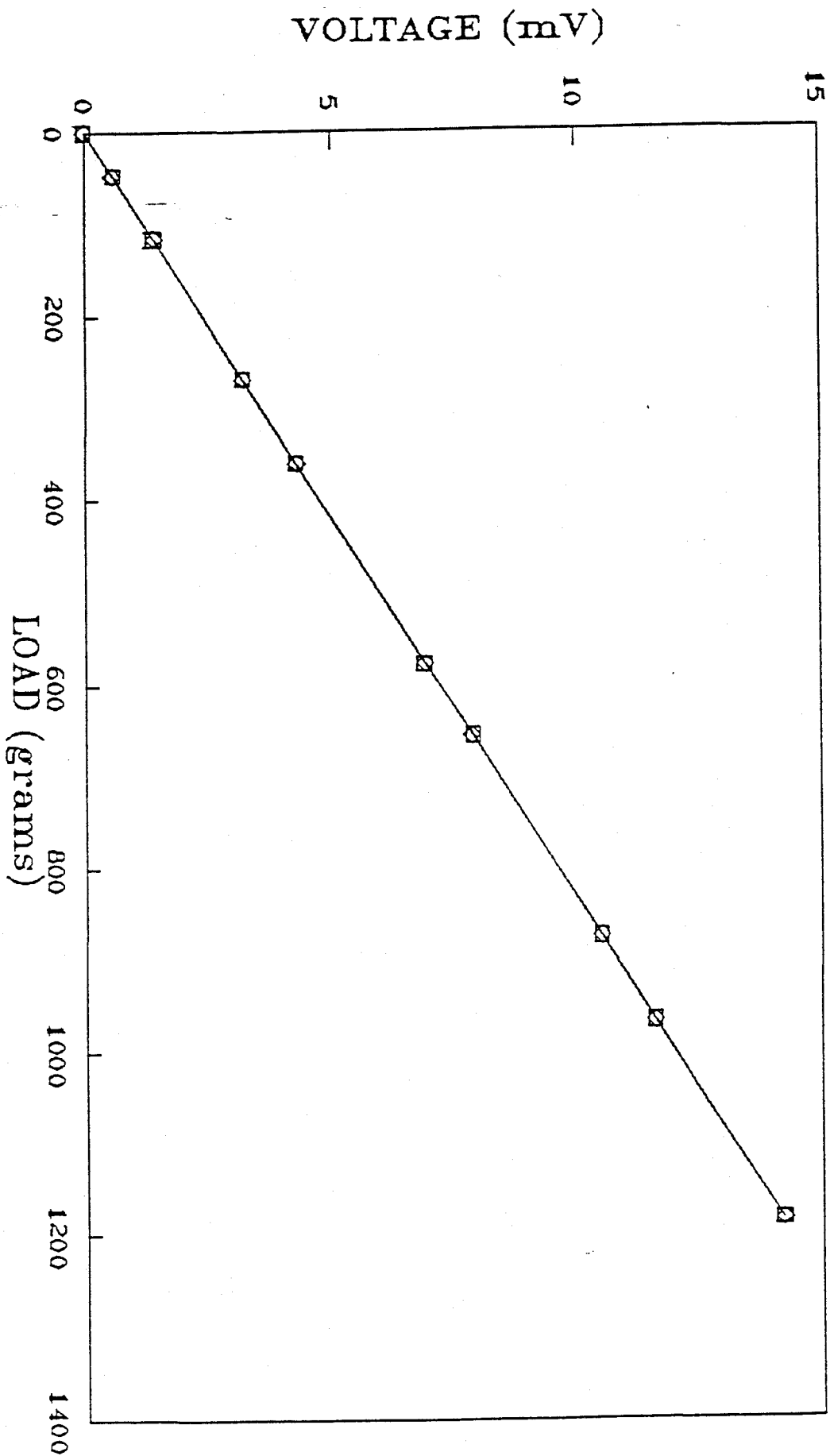
LOAD CELL CALIBRATION

LOAD CELL NO. C16387



LOAD CELL CALIBRATION

LOAD CELL NO. C16396

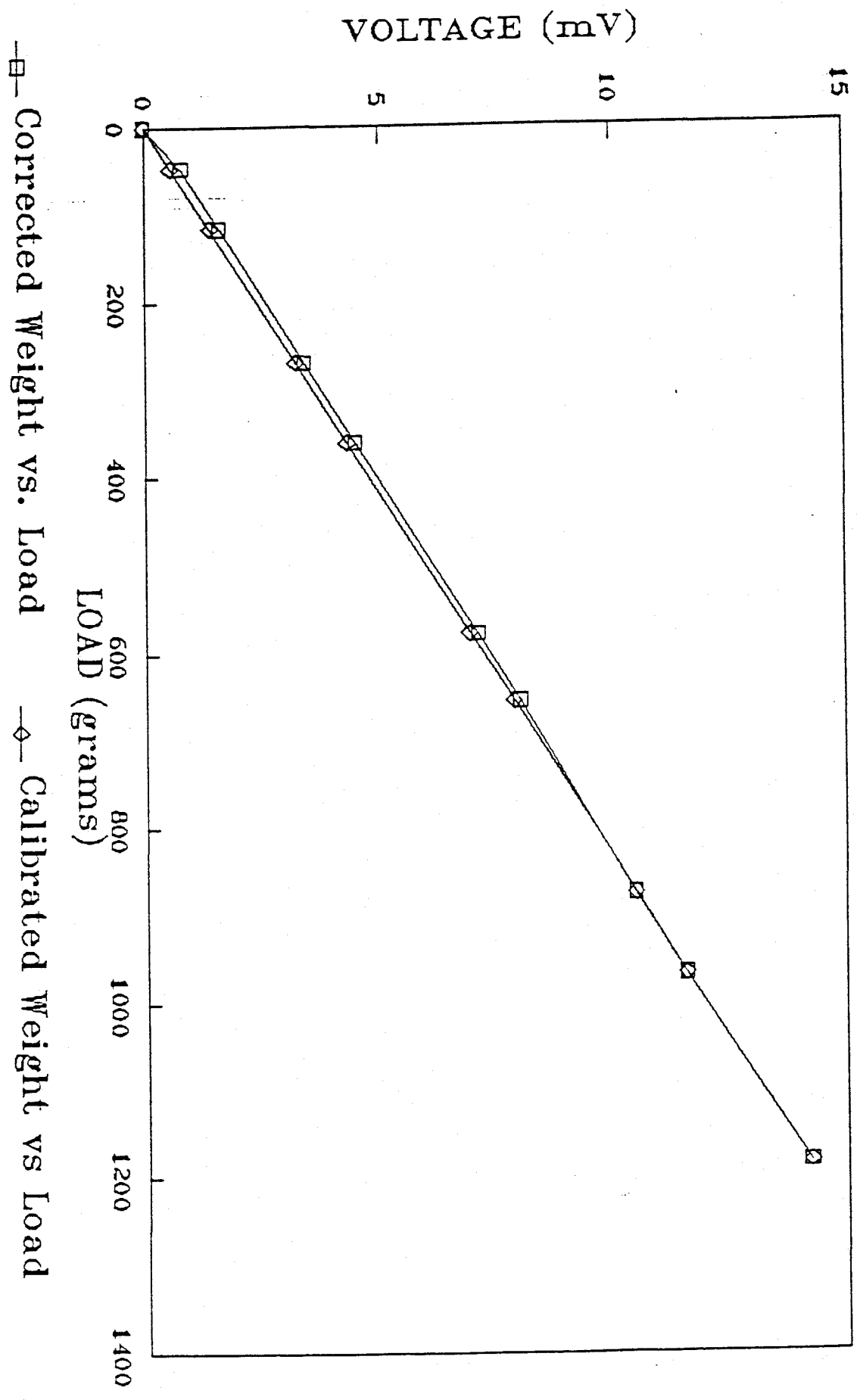


—■— Corrected Weight vs. Load

—◻— Calibrated Weight vs Load

LOAD CELL CALIBRATION

LOAD CELL NO. C16398

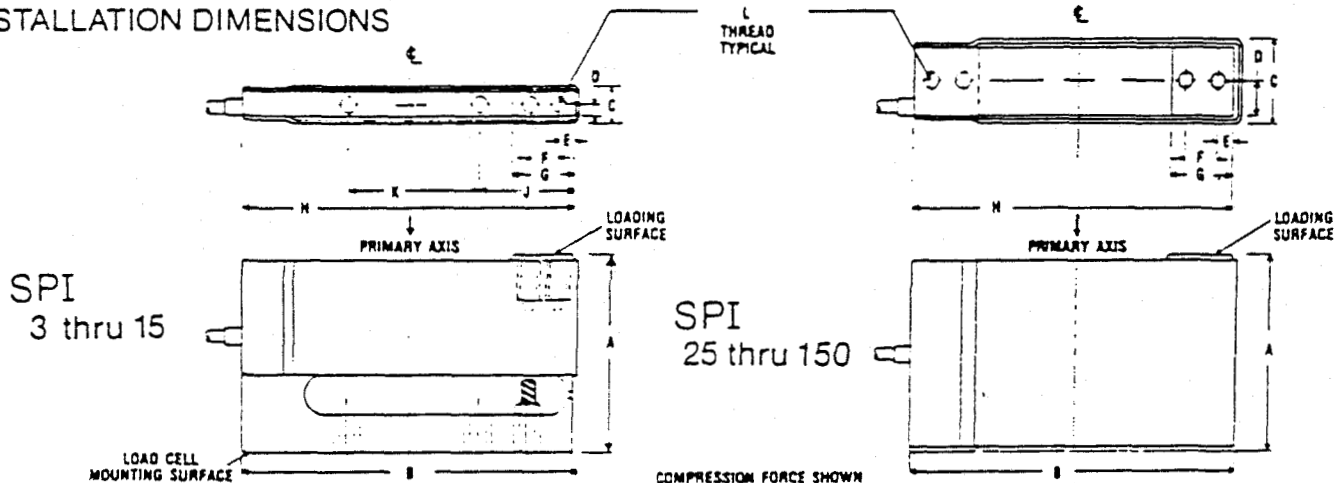


interface

ADVANCED FORCE MEASUREMENT

CALIBRATION CERTIFICATE INSTALLATION INFORMATION

INSTALLATION DIMENSIONS



MODEL	A	B	C	D	E	F	G	H	J	K	L	Torque (in-lb)
SPI-3	in. 3	5/8	1/2	3/8	1/4	.50	1	5	1 1/2	2	10-32	24
	mm 76	130	12.7	4.2	6.4	12.7	25	127	38	51		
SPI-7.5	in. 3	5/8	3/4	1/2	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm 76	130	19	6.4	6.4	12.7	25	127	38	51		
SPI-15	in. 3	5/8	1 1/4	1/2	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm 76	130	32	12.7	6.4	12.7	25	127	38	51		

MODEL	A	B	C	D*	E*	F*	G*	H	L	Torque (in-lb)
SPI-25 & 50	in. 3	5/8	1 1/4	1/2	1/4	.50	1	5	1/4-28	60
	mm 76	130	32	12.7	6.4	12.7	25	127		
SPI-100	in. 3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	60
	mm 76	156	32	12.7	6.4	25	38	152		
SPI-AA8-50	in. 3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	90
SPI-150	mm 76	156	32	12.7	6.4	25	38	152		

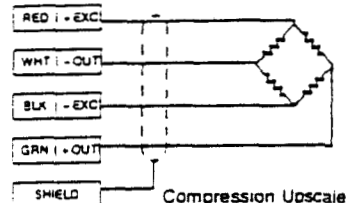
ng: Exceeding recommended torque levels may damage load cells.

ng Instructions: Fasten mounting surface to flat surface with two mounting screws. Fasten load receiver to loading surface with two screws.

ELECTRICAL INFORMATION

SPI Series is provided with 4-conductor shielded cable (AWG 28) 5 feet (1.5m) long.

Wiring color code complies with ISA S37.8 "Specifications and Tests for Strain Gage Force Transducers" and SMA Load Cell Terminology.



APPLICATION NOTES

- Single Point I load cells are designed for controlled environmental applications. In general they can be used anywhere a readout instrument is used.
- A moisture resistant coating is applied to protect the SPI Series from high humidity conditions up to and including 95% relative humidity and periodic exposure to condensation. These units are not intended for submerged operation.
- Mounting screws: thread engagement 3/8" - 1/2" (9 - 13mm).
- Mounting surface must be level to within 0.5°.
- Please exercise extreme caution while handling and installing these load cells.

6. Maximum Moment

Rated Capacity	Maximum Moment
0-3 lb.	9 lb-in.
0-7.5 lb.	22.5 lb-in.
0-15 lb.	45 lb-in.
0-25 lb.	125 lb-in.
0-50 lb.	250 lb-in.
0-100 lb.	500 lb-in.
0-150 lb.	500 lb-in.

- Applications involving impact/overload forces may require external stops. Request INTERFACE publication IFI #59 for additional information.

PERFORMANCE DATA

Nominal Output—mV/V	3
Input Resistance—Ohms	350 ± 50/-3.5
Output Resistance—Ohms	350 ± 3.5
Recommended Excitation—VDC	10
Non-Linearity—% Rated Output	< ±0.02
Hysteresis—% Rated Output	< ±0.02
Temperature Range, Compensated—°F	(-10 to +45°C) 15 to 115
Temperature Effect on Zero—% Rated Output/100°F	(% Rated Output/55.6°C) ±0.15
Zero Balance—% Rated Output	< ±5
Shift Error: Rated Load applied 3 inches (76 mm) for SPI-3 thru 15 and 5 inches (127 mm) for SPI-25 thru 150, from Load Cell centerline—% Rated Load/inch (% Rated Load/25.4 mm)	0.012

SINGLE POINT I LOAD CELL

Model: SPI-7.5

Date: 09-13-1991

Capacity: 7.5

(lbs) Serial: C16353

Output, Compression mV/V: 3.127

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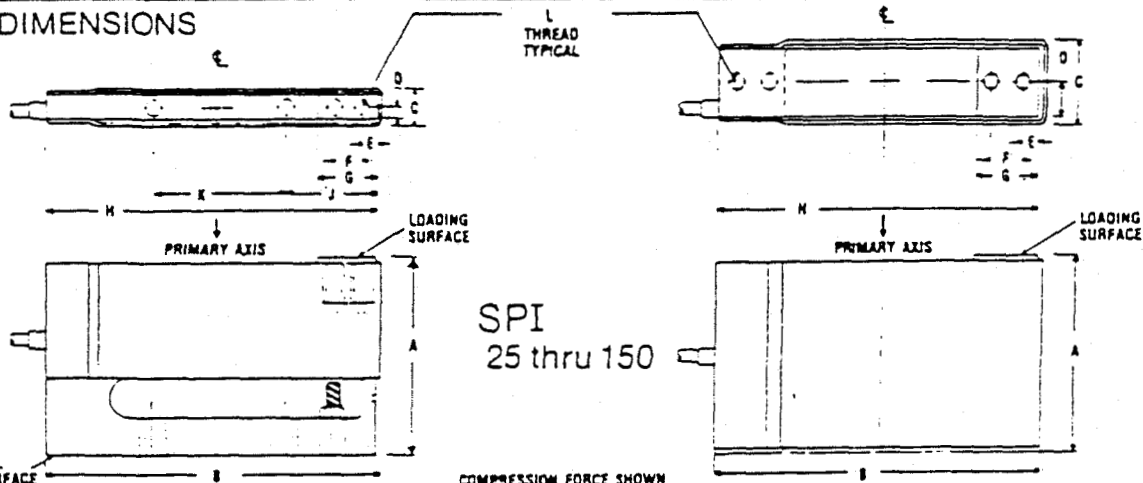
WARRANTY & CERTIFICATION STATEMENT ON OTHER SIDE

interface

ADVANCED FORCE MEASUREMENT

CALIBRATION CERTIFICATE INSTALLATION INFORMATION

INSTALLATION DIMENSIONS



MODEL		A	B	C	D	E	F	G	H	J	K	L	Torque (in.-lb.)
SPI-3	in.	3	5 1/8	1/2	3/16	1/4	.50	1	5	1 1/2	2	10-32	24
	mm	76	130	12.7	4.2	6.4	12.7	25	127	38	51		
SPI-7.5	in.	3	5 1/8	3/4	1/4	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	19	6.4	6.4	12.7	25	127	38	51		
SPI-15	in.	3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	32	12.7	6.4	12.7	25	127	38	51		

MODEL		A	B	C	D*	E*	F*	G*	H	L	Torque (in.-lb.)
SPI-25 & 50	in.	3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1/4-28	60
	mm	76	130	32	12.7	6.4	12.7	25	127		
SPI-100	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	60
	mm	76	156	32	12.7	6.4	25	38	152		
SPI-AA8-50 SPI-150	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	90
	mm	76	156	32	12.7	6.4	25	38	152		

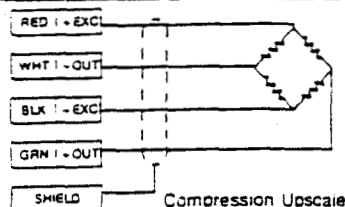
* Exceeding recommended torque levels may damage load cells.

Installation Instructions: Fasten mounting surface to flat surface with two mounting screws. Fasten load receiver to loading surface with two screws.

ELECTRICAL INFORMATION

SPI Series is provided with 4-conductor shielded cable (AWG 28) 5 feet (1.5m) long.

Wiring color code complies with ISA S37.8 "Specifications and Tests for Strain Gage Force Transducers" and SMA Load Cell Terminology.



APPLICATION NOTES

- Single Point I load cells are designed for controlled environmental applications. In general they can be used anywhere a readout instrument is used.
- A moisture resistant coating is applied to protect the SPI Series from high humidity conditions up to and including 95% relative humidity and periodic exposure to condensation. These units are not intended for submerged operation.
- Mounting screws: thread engagement 3/8" - 1/2" (9 - 13mm).
- Mounting surface must be level to within 0.5°.
- Please exercise extreme caution while handling and installing these load cells.

6. Maximum Moment

Rated Capacity	Maximum Moment
0-3 lb.	9 lb.-in.
0-7.5 lb.	22.5 lb.-in.
0-15 lb.	45 lb.-in.
0-25 lb.	125 lb.-in.
0-50 lb.	250 lb.-in.
0-100 lb.	500 lb.-in.
0-150 lb.	500 lb.-in.

- Applications involving impact/overload forces may require external stops. Request INTERFACE publication IFI #59 for additional information.

PERFORMANCE DATA

Nominal Output—mV/V	3
Input Resistance—Ohms	350 + 50/-3.5
Output Resistance—Ohms	350 ± 3.5
Recommended Excitation—VDC	10
Non-Linearity—% Rated Output	< ±0.02
Hysteresis—% Rated Output	< ±0.02
Temperature Range, Compensated—°F	(-10 to +45°C)
Temperature Effect on Zero—% Rated Output/100°F	(% Rated Output/55.6°C) ±0.15
Zero Balance—% Rated Output	< ±5
Shift Error: Rated Load applied 3 inches (76 mm) for SPI-3 thru 15 and 5 inches (127 mm) for SPI-25 thru 150, from Load Cell centerline—% Rated Load/inch (% Rated Load/25.4 mm)	0.012

SINGLE POINT I LOAD CELL

Model: SPI-7.5

Date: 09-13-1991

Capacity: 7.5

(lbs) Serial: C16355

Output, Compression mV/V: 3.133

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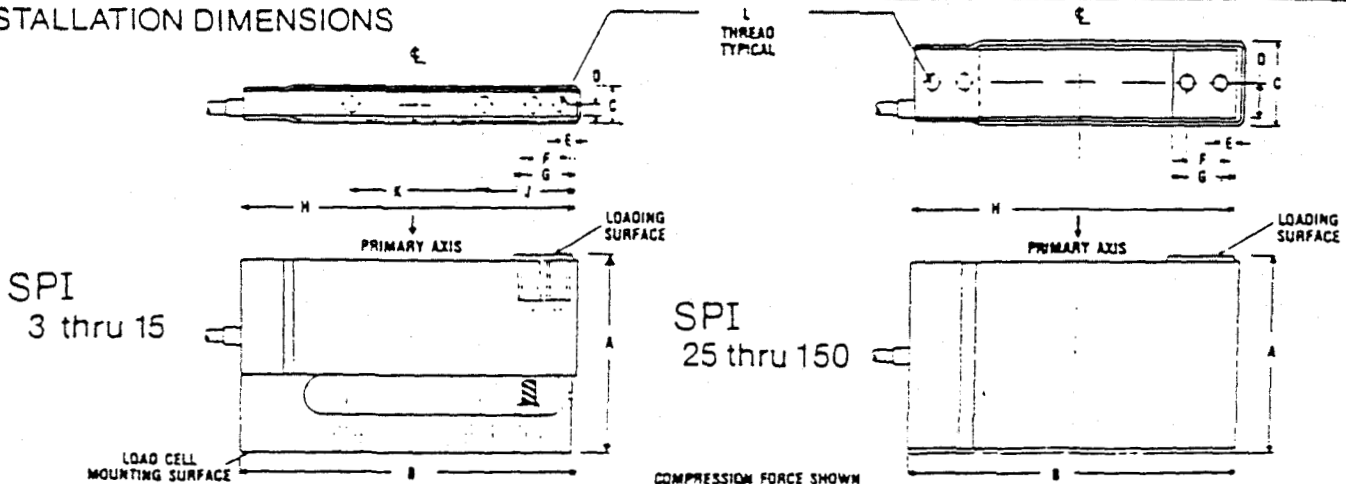
WARRANTY & CERTIFICATION STATEMENT ON OTHER SIDE

Interface

ADVANCED FORCE MEASUREMENT

CALIBRATION CERTIFICATE INSTALLATION INFORMATION

INSTALLATION DIMENSIONS



MODEL	A	B	C	D	E	F	G	H	J	K	L	Torque (in-lb)
SPI-3	in. 3	5 1/8	1/2	3/8	1/4	.50	1	5	1 1/2	2	10-32	24
	mm 76	130	12.7	4.2	6.4	12.7	25	127	38	51		
SPI-7.5	in. 3	5 1/8	3/4	1/4	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm 76	130	19	6.4	6.4	12.7	25	127	38	51		
SPI-15	in. 3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm 76	130	32	12.7	6.4	12.7	25	127	38	51		

MODEL	A	B	C	D*	E*	F*	G*	H	L	Torque (in-lb)
SPI-25 & 50	in. 3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1/4-28	60
	mm 76	130	32	12.7	6.4	12.7	25	127		
SPI-100	in. 3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	60
	mm 76	156	32	12.7	6.4	25	38	152		
SPI-AAB-50	in. 3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	90
SPI-150	mm 76	156	32	12.7	6.4	25	38	152		

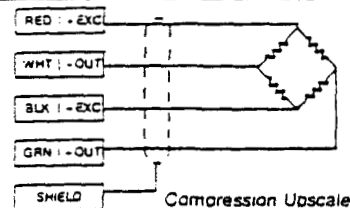
*Typical two places on all SPIs 25 thru 150

Mounting Instructions: Fasten mounting surface to flat surface with two mounting screws. Fasten load receiver to loading surface with two screws.

ELECTRICAL INFORMATION

SPI Series is provided with 4-conductor shielded cable (AWG 28) 5 feet (1.5m) long.

Wiring color code complies with ISA S37.8 "Specifications and Tests for Strain Gage Force Transducers" and SMA Load Cell Terminology.



APPLICATION NOTES

- Single Point I load cells are designed for controlled environmental applications. In general they can be used anywhere a readout instrument is used.
- A moisture resistant coating is applied to protect the SPI Series from high humidity conditions up to and including 95% relative humidity and periodic exposure to condensation. These units are not intended for submerged operation.
- Mounting screws: thread engagement 3/8" - 1/2" (9 - 13mm).
- Mounting surface must be level to within 0.5°.
- Please exercise extreme caution while handling and installing these load cells.

6. Maximum Moment

Rated Capacity	Maximum Moment
0-3 lb.	9 lb-in.
0-7.5 lb.	22.5 lb-in.
0-15 lb.	45 lb-in.
0-25 lb.	125 lb-in.
0-50 lb.	250 lb-in.
0-100 lb.	500 lb-in.
0-150 lb.	500 lb-in.

- Applications involving impact/overload forces may require external stops. Request INTERFACE publication IFI #59 for additional information.

PERFORMANCE DATA

Nominal Output—mV/V	3
Input Resistance—Ohms	350 ± 50 / -3.5
Output Resistance—Ohms	350 ± 3.5
Recommended Excitation—VDC	10
Non-Linearity—% Rated Output	< ±0.02
Hysteresis—% Rated Output	< ±0.02
Temperature Range	
Compensated—°F	(-10 to +45°C) 15 to 115
Temperature Effect on Zero—	
% Rated Output/100°F	(% Rated Output/55.6°C) ±0.15
Zero Balance—% Rated Output	< ±5
Shift Error: Rated Load applied 3 inches (76 mm) for SPI-3 thru 15 and 5 inches (127 mm) for SPI-25 thru 150, from Load Cell centerline—	
% Rated Load/inch (% Rated Load/25.4 mm)	0.012

SINGLE POINT I LOAD CELL

Model: SPI-7.5

Date: 09-13-1991

Capacity: 7.5

(lbs) Serial: C16359

Output, Compression mV/V: 3.128

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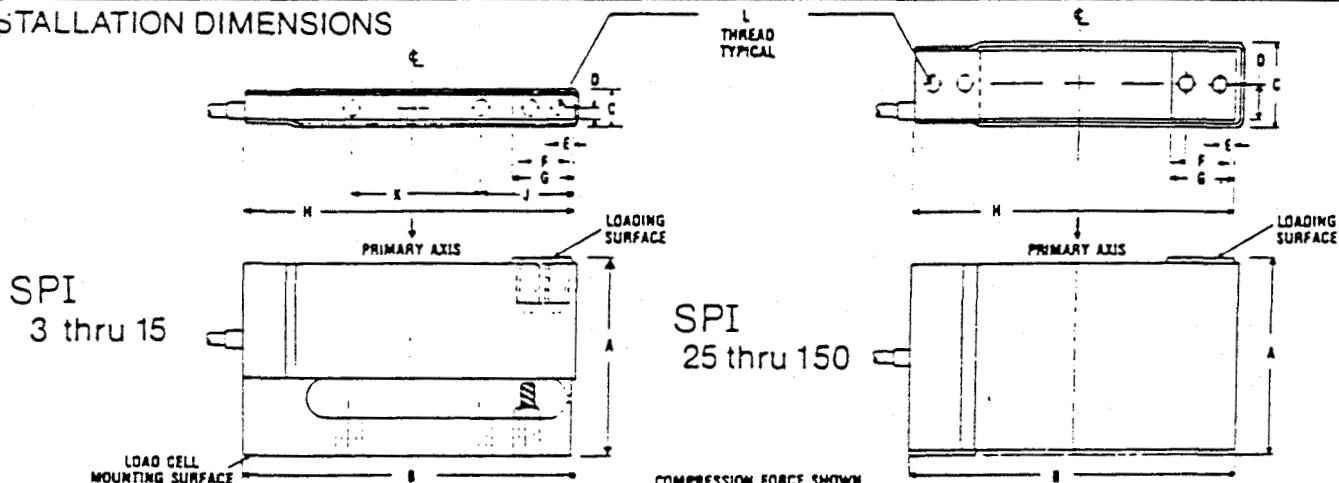
WARRANTY & CERTIFICATION STATEMENT ON OTHER SIDE

Interface

ADVANCED FORCE MEASUREMENT

CALIBRATION CERTIFICATE INSTALLATION INFORMATION

INSTALLATION DIMENSIONS



MODEL		A	B	C	D	E	F	G	H	J	K	L	Torque in-lb
SPI-3	in.	3	5 1/8	1/2	3/16	1/4	.50	1	5	1 1/2	2	10-32	24
	mm	76	130	12.7	4.2	6.4	12.7	25	127	38	51		
SPI-7.5	in.	3	5 1/8	3/4	1/4	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	19	6.4	6.4	12.7	25	127	38	51		
SPI-15	in.	3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	32	12.7	6.4	12.7	25	127	38	51		

MODEL		A	B	C	D*	E*	F*	G*	H	L	Torque in-lb
SPI-25 & 50	in.	3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1/4-28	60
	mm	76	130	32	12.7	6.4	12.7	25	127		
SPI-100	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	60
	mm	76	156	32	12.7	6.4	25	38	152		
SPI-AAB-50 SPI-150	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	90
	mm	76	156	32	12.7	6.4	25	38	152		

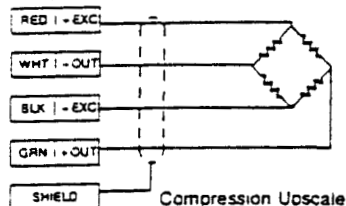
*Typical two places on all SPIs 25 thru 150

ing Instructions: Fasten mounting surface to flat surface with two mounting screws. Fasten load receiver to loading surface with two screws.

ELECTRICAL INFORMATION

SPI Series is provided with 4-conductor shielded cable (AWG 28) 5 feet (1.5m) long.

Wiring color code complies with ISA S37.8 "Specifications and Tests for Strain Gage Force Transducers" and SMA Load Cell Terminology.



APPLICATION NOTES

- Single Point I load cells are designed for controlled environmental applications. In general they can be used anywhere a readout instrument is used.
- A moisture resistant coating is applied to protect the SPI Series from high humidity conditions up to and including 95% relative humidity and periodic exposure to condensation. These units are not intended for submerged operation.
- Mounting screws: thread engagement 3/8" - 1/2" (9 - 13mm).
- Mounting surface must be level to within 0.5°.
- Please exercise extreme caution while handling and installing these load cells.

6. Maximum Moment

Rated Capacity	Maximum Moment
0-3 lb.	9 lb-in.
0-7.5 lb.	22.5 lb-in.
0-15 lb.	45 lb-in.
0-25 lb.	125 lb-in.
0-50 lb.	250 lb-in.
0-100 lb.	500 lb-in.
0-150 lb.	500 lb-in.

- Applications involving impact/overload forces may require external stops. Request INTERFACE publication IFI #59 for additional information.

PERFORMANCE DATA

Nominal Output—mV/V	3
Input Resistance—Ohms	350 ± 50/-3.5
Output Resistance—Ohms	350 ± 3.5
Recommended Excitation—VDC	10
Non-Linearity—% Rated Output	< ±0.02
Hysteresis—% Rated Output	< ±0.02
Temperature Range	
Compensated—°F	(-10 to +45°C)
Temperature Effect on Zero—	
% Rated Output/100°F	(% Rated Output/55.6°C)
Zero Balance—% Rated Output	< ±5
Shift Error: Rated Load applied 3 inches (76 mm) for SPI-3 thru 15 and 5 inches (127 mm) for SPI-25 thru 150, from Load Cell centerline—	
% Rated Load/inch (% Rated Load/25.4 mm)	0.012

SINGLE POINT I LOAD CELL

Model: SPI-7.5

Date: 09-13-1991

Capacity: 7.5

(lbs) Serial: C16360

Output, Compression mV/V: 3.242

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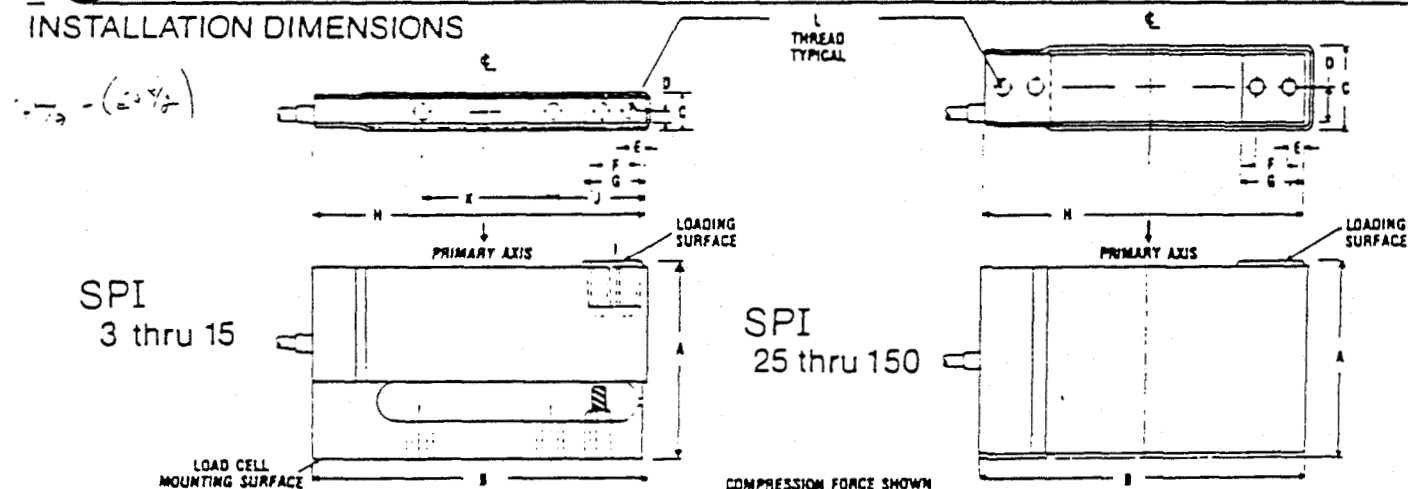
WARRANTY & CERTIFICATION STATEMENT ON OTHER SIDE

Interface

ADVANCED FORCE MEASUREMENT

CALIBRATION CERTIFICATE INSTALLATION INFORMATION

INSTALLATION DIMENSIONS



MODEL		A	B	C	D	E	F	G	H	J	K	L	Torque in-lb
SPI-3	in.	3	5 1/8	1/2	3/16	1/4	.50	1	5	1 1/2	2	10-32	24
	mm	76	130	12.7	4.2	6.4	12.7	25	127	38	51		
SPI-7.5	in.	3	5 1/8	3/4	1/4	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	19	6.4	6.4	12.7	25	127	38	51		
SPI-15	in.	3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	32	12.7	6.4	12.7	25	127	38	51		

MODEL		A	B	C	D*	E*	F*	G*	H	L	Torque in-lb
SPI-25 & 50	in.	3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1/4-28	60
	mm	76	130	32	12.7	6.4	12.7	25	127		
SPI-100	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	60
	mm	76	156	32	12.7	6.4	25	38	152		
SPI-AA8-50 SPI-150	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	90
	mm	76	156	32	12.7	6.4	25	38	152		

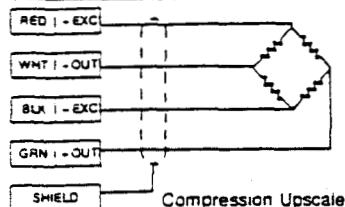
*Exceeding recommended torque levels may damage load cells.

Wiring Instructions: Fasten mounting surface to flat surface with two mounting screws. Fasten load receiver to loading surface with two screws.

ELECTRICAL INFORMATION

SPI Series is provided with 4-conductor shielded cable (AWG 28) 5 feet (1.5m) long.

Wiring color code complies with ISA S37.8 "Specifications and Tests for Strain Gage Force Transducers" and SMA Load Cell Terminology.



Compression Upscale

APPLICATION NOTES

1. Single Point I load cells are designed for controlled environmental applications. In general they can be used anywhere a readout instrument is used.
2. A moisture resistant coating is applied to protect the SPI Series from high humidity conditions up to and including 95% relative humidity and periodic exposure to condensation. These units are not intended for submerged operation.
3. Mounting screws: thread engagement 3/8" - 1/2" (9 - 13mm).
4. Mounting surface must be level to within 0.5°.
5. Please exercise extreme caution while handling and installing these load cells.

6. Maximum Moment

Rated Capacity	Maximum Moment
0-3 lb.	9 lb-in.
0-7.5 lb.	22.5 lb-in.
0-15 lb.	45 lb-in.
0-25 lb.	125 lb-in.
0-50 lb.	250 lb-in.
0-100 lb.	500 lb-in.
0-150 lb.	500 lb-in.

7. Applications involving impact/overload forces may require external stops. Request INTERFACE publication IFI #59 for additional information.

PERFORMANCE DATA

Nominal Output—mV/V	3
Input Resistance—Ohms	350 ± 50/-3.5
Output Resistance—Ohms	350 ± 3.5
Recommended Excitation—VDC	10
Non-Linearity—% Rated Output	< ±0.02
Hysteresis—% Rated Output	< ±0.02
Temperature Range, compensated—°F	(-10 to +45°C)
Temperature Effect on Zero—% Rated Output/100°F	(% Rated Output/55.6°C) ±0.15
Zero Balance—% Rated Output	< ±5
Shift Error: Rated Load applied 3 inches (76 mm) for SPI-3 thru 15 and 5 inches (127 mm) for SPI-25 thru 150, from Load Cell centerline—% Rated Load/inch (% Rated Load/25.4 mm)	0.012

SINGLE POINT I LOAD CELL

Model: SPI-7.5

Date: 11-19-1991

Capacity: 7.5

(lbs) Serial: C16364

Output, Compression mV/V: 3.163

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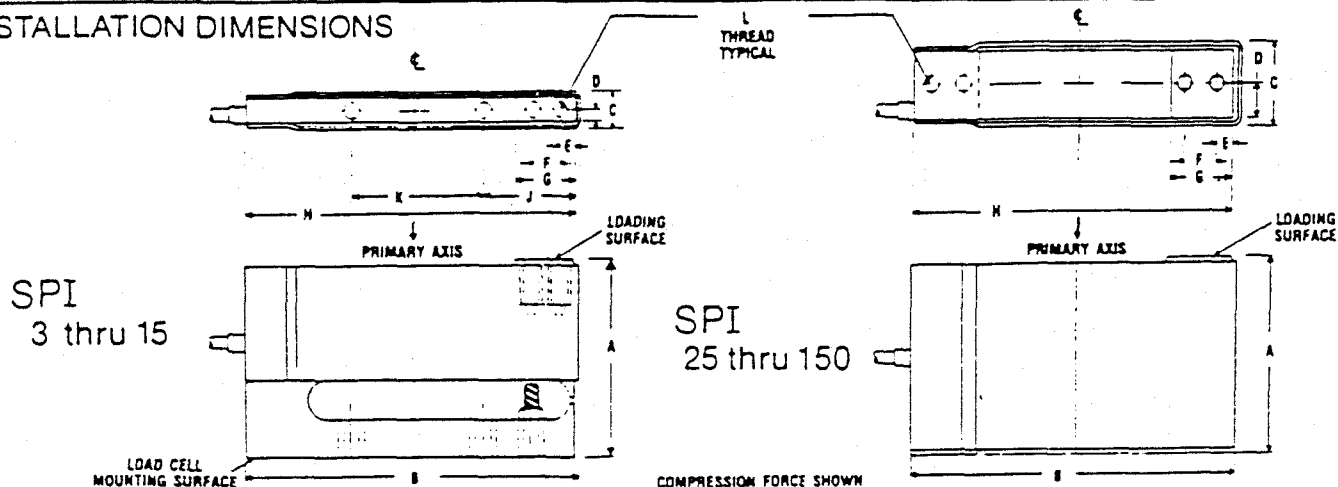
Telex: 825-882

WARRANTY & CERTIFICATION STATEMENT ON OTHER SIDE

interface

ADVANCED FORCE MEASUREMENT

INSTALLATION DIMENSIONS



MODEL	A	B	C	D	E	F	G	H	J	K	L	Torque in-lb
SPI-3	in. 3	5 1/8	1/2	3/16	1/4	.50	1	5	1 1/2	2	10-32	24
	mm 76	130	12.7	4.2	6.4	12.7	25	127	38	51		
SPI-7.5	in. 3	5 1/8	3/4	1/4	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm 76	130	19	6.4	6.4	12.7	25	127	38	51		
SPI-15	in. 3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm 76	130	32	12.7	6.4	12.7	25	127	38	51		

MODEL	A	B	C	D*	E*	F*	G*	H	L	Torque in-lb
SPI-25 & 50	in. 3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1/4-28	60
	mm 76	130	32	12.7	6.4	12.7	25	127		
SPI-100	in. 3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	60
	mm 76	156	32	12.7	6.4	25	38	152		
SPI-AAB-50	in. 3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	90
SPI-150	mm 76	156	32	12.7	6.4	25	38	152		

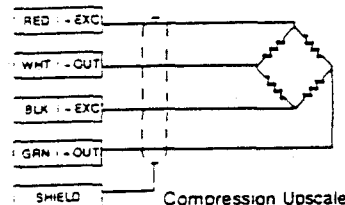
Warning: Exceeding recommended torque levels may damage load cells.

Mounting Instructions: Fasten mounting surface to flat surface with two mounting screws. Fasten load receiver to loading surface with two screws.

ELECTRICAL INFORMATION

SPI Series is provided with 4-conductor shielded cable (AWG 28) 5 feet (1.5m) long.

Wiring color code complies with ISA S37.8 "Specifications and Tests for Strain Gage Force Transducers" and SMA Load Cell Terminology.



APPLICATION NOTES

1. Single Point I load cells are designed for controlled environmental applications. In general they can be used anywhere a readout instrument is used.
2. A moisture resistant coating is applied to protect the SPI Series from high humidity conditions up to and including 95% relative humidity and periodic exposure to condensation. These units are not intended for submerged operation.
3. Mounting screws: thread engagement 3/8" - 1/2" (9 - 13mm).
4. Mounting surface must be level to within 0.5°.
5. Please exercise extreme caution while handling and installing these load cells.

6. Maximum Moment

Rated Capacity	Maximum Moment
0-3 lb.	9 lb-in.
0-7.5 lb.	22.5 lb-in.
0-15 lb.	45 lb-in.
0-25 lb.	125 lb-in.
0-50 lb.	250 lb-in.
0-100 lb.	500 lb-in.
0-150 lb.	500 lb-in.

7. Applications involving impact/overload forces may require external stops. Request INTERFACE publication IF1 #59 for additional information.

PERFORMANCE DATA

Nominal Output—mV/V	3
Input Resistance—Ohms	350 + 50/-3.5
Output Resistance—Ohms	350 ± 3.5
Recommended Excitation—VDC	10
Non-Linearity—% Rated Output	< ±0.02
Hysteresis—% Rated Output	< ±0.02
Temperature Range	
Compensated—°F	(-10 to +45°C)
Temperature Effect on Zero—	
% Rated Output/100°F	(% Rated Output/55.6°C)
Zero Balance—% Rated Output	< ±0.15
Shift Error: Rated Load applied 3 inches (76 mm) for SPI-3	
thru 15 and 5 inches (127 mm) for SPI-25 thru 150, from	
Load Cell centerline—	
% Rated Load/inch (% Rated Load/25.4 mm)	0.012

SINGLE POINT I LOAD CELL

Model: SPI-7.5

Date: 09-13-1991

Capacity: 7.5

(lbs) Serial: C16373

Output, Compression mV/V: 3.106

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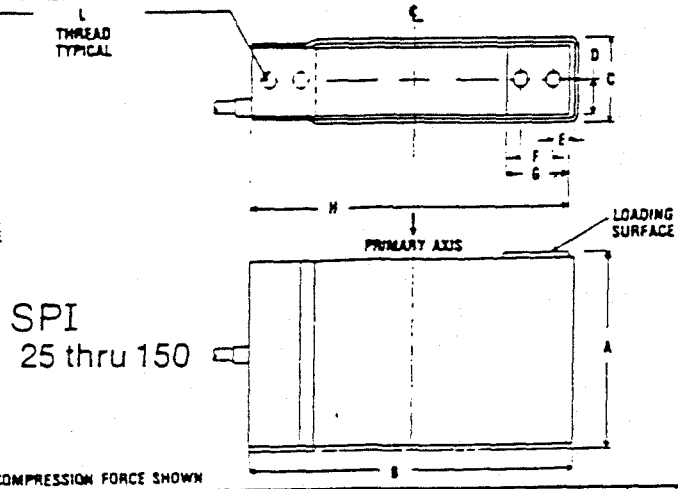
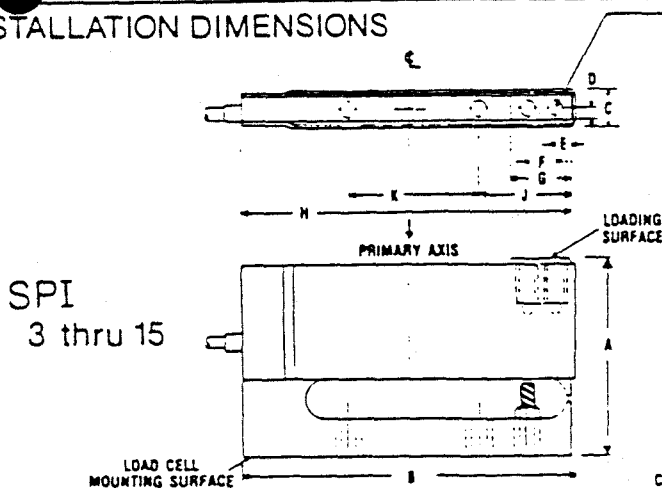
WARRANTY & CERTIFICATION STATEMENT ON OTHER SIDE

Interface

ADVANCED FORCE MEASUREMENT

INSTALLATION DIMENSIONS

CALIBRATION CERTIFICATE INSTALLATION INFORMATION



MODEL	A	B	C	D	E	F	G	H	J	K	L	Torque (in-lb)
SPI-3	in. 3	5 1/8	1/2	3/16	1/4	.50	1	5	1 1/2	2	10-32	24
	mm 76	130	12.7	4.2	6.4	12.7	25	127	38	51		
SPI-7.5	in. 3	5 1/8	3/4	1/4	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm 76	130	19	6.4	6.4	12.7	25	127	38	51		
SPI-15	in. 3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm 76	130	32	12.7	6.4	12.7	25	127	38	51		

MODEL	A	B	C	D*	E*	F*	G*	H	L	Torque (in-lb)
SPI-25 & 50	in. 3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1/4-28	60
	mm 76	130	32	12.7	6.4	12.7	25	127		
SPI-100	in. 3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	60
	mm 76	156	32	12.7	6.4	25	38	152		
SPI-AAB-50	in. 3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	90
SPI-150	mm 76	156	32	12.7	6.4	25	38	152		

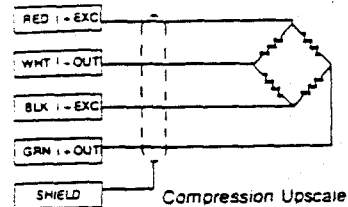
Warning: Exceeding recommended torque levels may damage load cells.

Installation Instructions: Fasten mounting surface to flat surface with two mounting screws. Fasten load receiver to loading surface with two screws.

ELECTRICAL INFORMATION

SPI Series is provided with 4-conductor shielded cable (AWG 28) 5 feet (1.5m) long.

Wiring color code complies with ISA S37.8 "Specifications and Tests for Strain Gage Force Transducers" and SMA Load Cell Terminology.



APPLICATION NOTES

- Single Point I load cells are designed for controlled environmental applications. In general they can be used anywhere a readout instrument is used.
- A moisture resistant coating is applied to protect the SPI Series from high humidity conditions up to and including 95% relative humidity and periodic exposure to condensation. These units are not intended for submerged operation.
- Mounting screws: thread engagement 3/8" - 1/2" (9 - 13mm).
- Mounting surface must be level to within 0.5°.
- Please exercise extreme caution while handling and installing these load cells.

6. Maximum Moment

Rated Capacity	Maximum Moment
0-3 lb.	9 lb-in.
0-7.5 lb.	22.5 lb-in.
0-15 lb.	45 lb-in.
0-25 lb.	125 lb-in.
0-50 lb.	250 lb-in.
0-100 lb.	500 lb-in.
0-150 lb.	500 lb-in.

- Applications involving impact/overload forces may require external stops. Request INTERFACE publication IFI #59 for additional information.

PERFORMANCE DATA

Nominal Output—mV/V	3
Input Resistance—Ohms	350 ± 50/-3.5
Output Resistance—Ohms	350 ± 3.5
Recommended Excitation—VDC	10
Non-Linearity—% Rated Output	< ±0.02
Hysteresis—% Rated Output	< ±0.02
Temperature Range, compensated—°F	(-10 to +45°C) 15 to 115
Temperature Effect on Zero—% Rated Output/100°F	(% Rated Output/55.6°C) ±0.15
Zero Balance—% Rated Output	< ±5
Shift Error: Rated Load applied 3 inches (76 mm) for SPI-3 thru 15 and 5 inches (127 mm) for SPI-25 thru 150, from Load Cell centerline—% Rated Load/inch (% Rated Load/25.4 mm)	0.012

SINGLE POINT I LOAD CELL

Model: SPI-7.5

Date: 09-13-1991

Capacity: 7.5

(lbs) Serial: C16374

Output, Compression mV/V: 3.114

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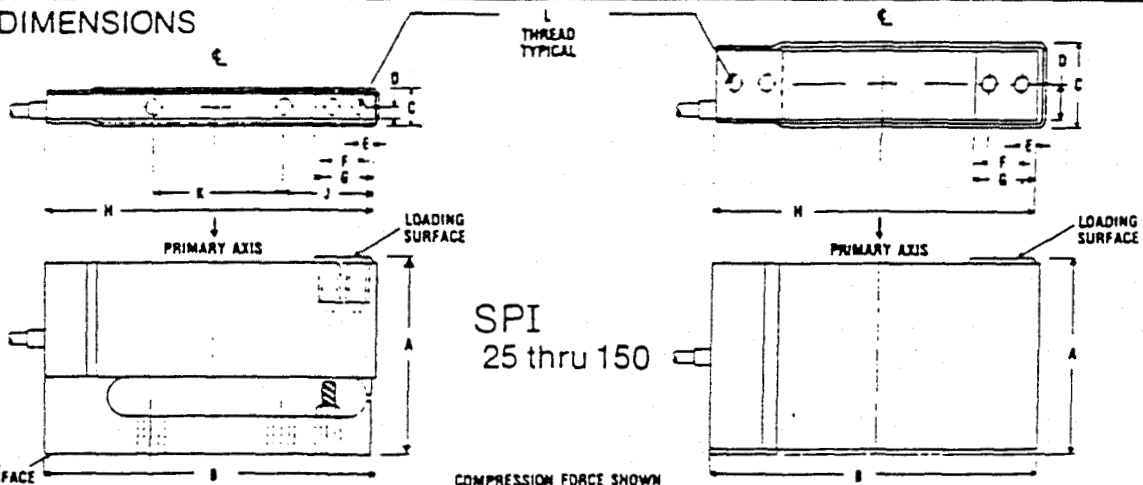
WARRANTY & CERTIFICATION STATEMENT ON OTHER SIDE

Interface

ADVANCED FORCE MEASUREMENT

CALIBRATION CERTIFICATE INSTALLATION INFORMATION

INSTALLATION DIMENSIONS



MODEL		A	B	C	D	E	F	G	H	J	K	L	Torque in-lb
SPI-3	in.	3	5 1/8	1/2	3/16	1/4	.50	1	5	1 1/2	2	10-32	24
	mm	76	130	12.7	4.2	6.4	12.7	25	127	38	51		
SPI-7.5	in.	3	5 1/8	3/4	1/4	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	19	6.4	6.4	12.7	25	127	38	51		
SPI-15	in.	3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	32	12.7	6.4	12.7	25	127	38	51		

MODEL		A	B	C	D*	E*	F*	G*	H	L	Torque in-lb
SPI-25 & 50	in.	3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1/4-28	60
	mm	76	130	32	12.7	6.4	12.7	25	127		
SPI-100	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	60
	mm	76	156	32	12.7	6.4	25	38	152		
SPI-AAB-50 SPI-150	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	90
	mm	76	156	32	12.7	6.4	25	38	152		

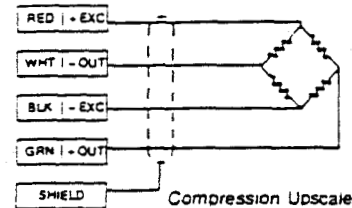
Warning: Exceeding recommended torque levels may damage load cells.

Fastening Instructions: Fasten mounting surface to flat surface with two mounting screws. Fasten load receiver to loading surface with two screws.

ELECTRICAL INFORMATION

SPI Series is provided with 4-conductor shielded cable (AWG 28) 5 feet (1.5m) long.

Wiring color code complies with ISA S37.8 "Specifications and Tests for Strain Gage Force Transducers" and SMA Load Cell Terminology.



APPLICATION NOTES

1. Single Point I load cells are designed for controlled environmental applications. In general they can be used anywhere a readout instrument is used.
2. A moisture resistant coating is applied to protect the SPI Series from high humidity conditions up to and including 95% relative humidity and periodic exposure to condensation. These units are not intended for submerged operation.
3. Mounting screws: thread engagement 3/8" - 1/2" (9 - 13mm).
4. Mounting surface must be level to within 0.5°.
5. Please exercise extreme caution while handling and installing these load cells.

6. Maximum Moment

Rated Capacity	Maximum Moment
0-3 lb.	9 lb-in.
0-7.5 lb.	22.5 lb-in.
0-15 lb.	45 lb-in.
0-25 lb.	125 lb-in.
0-50 lb.	250 lb-in.
0-100 lb.	500 lb-in.
0-150 lb.	500 lb-in.

7. Applications involving impact/overload forces may require external stops. Request INTERFACE publication IF1 #59 for additional information.

PERFORMANCE DATA

Nominal Output—mV/V	3
Input Resistance—Ohms	350 + 50/-3.5
Output Resistance—Ohms	350 ± 3.5
Recommended Excitation—VDC	10
Non-Linearity—% Rated Output	< ± 0.02
Hysteresis—% Rated Output	< ± 0.02
Temperature Range, compensated—°F	(-10 to +45°C) 15 to 115
Temperature Effect on Zero—% Rated Output/100°F	(% Rated Output/55.6°C) ± 0.15
Zero Balance—% Rated Output	< ± 5
Shift Error: Rated Load applied 3 inches (76 mm) for SPI-3 thru 15 and 5 inches (127 mm) for SPI-25 thru 150, from Load Cell centerline—% Rated Load/inch (% Rated Load/25.4 mm)	0.012

SINGLE POINT I LOAD CELL

Model: SPI-7.5

Date: 09-13-1991

Capacity: 7.5

(lbs) Serial: C16375

Output, Compression mV/V: 3.151

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WARRANTY & CERTIFICATION STATEMENT ON OTHER SIDE

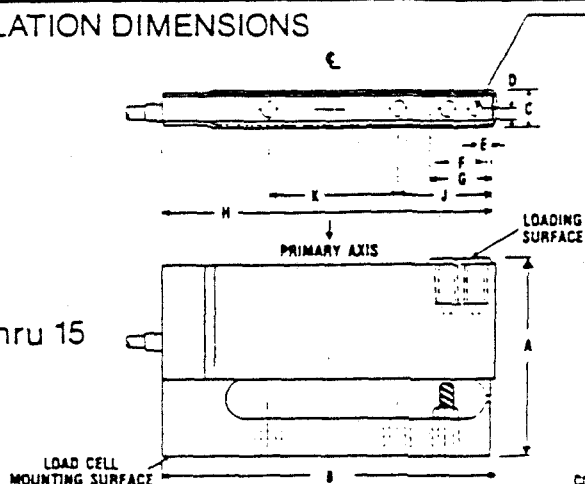
Interface

ADVANCED FORCE MEASUREMENT

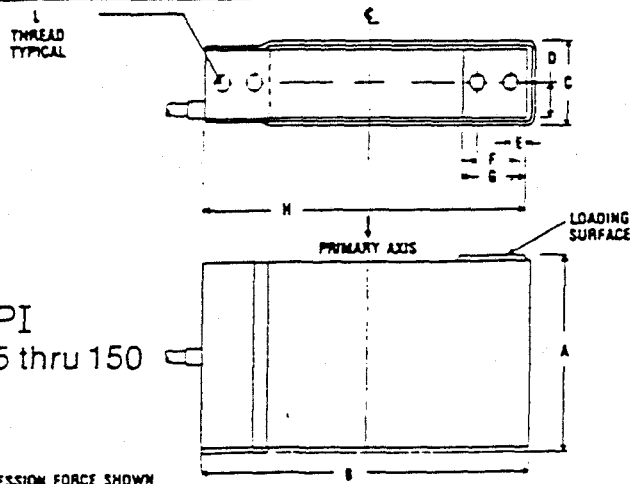
INSTALLATION DIMENSIONS

CALIBRATION CERTIFICATE INSTALLATION INFORMATION

SPI
3 thru 15



SPI
25 thru 150



SPECS												Torque (in-lb)	
MODEL		A	B	C	D	E	F	G	H	J	K	L	
SPI-3	in.	3	5/8	1/2	3/16	1/4	.50	1	5	1 1/2	2	10-32	24
	mm	76	130	12.7	4.2	6.4	12.7	25	127	38	51		
SPI-7.5	in.	3	5/8	3/4	1/4	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	19	6.4	6.4	12.7	25	127	38	51		
SPI-15	in.	3	5/8	1 1/4	1/2	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	32	12.7	6.4	12.7	25	127	38	51		

MODEL		A	B	C	D*	E*	F*	G*	H	L	Torque in-lb
SPI-25 & 50	in.	3	5⅞	1¼	½	¼	.50	1	5	¼-28	60
	mm	76	130	32	12.7	6.4	12.7	25	127		
SPI-100	in.	3	6⅞	1¼	½	¼	1.00	1.5	6	¼-28	60
	mm	76	156	32	12.7	6.4	25	38	152		
SPI-AAB-50 SPI-150	in.	3	6⅞	1¼	½	¼	1.00	1.5	6	¼-28	90
	mm	76	156	32	12.7	6.4	25	38	152		

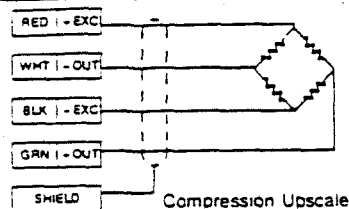
Warning: Exceeding recommended torque levels may damage load cells.

Installation Instructions: Fasten mounting surface to flat surface with two mounting screws. Fasten load receiver to loading surface with two screws.

ELECTRICAL INFORMATION

SPI Series is provided with 4-conductor shielded cable (AWG 28) 5 feet (1.5m) long.

Wiring color code complies with ISA S37.8 "Specifications and Tests for Strain Gage Force Transducers" and SMA Load Cell Terminology.



APPLICATION NOTES

1. Single Point I load cells are designed for controlled environmental applications. In general they can be used anywhere a readout instrument is used.
2. A moisture resistant coating is applied to protect the SPI Series from high humidity conditions up to and including 95% relative humidity and periodic exposure to condensation. These units are not intended for submerged operation.
3. Mounting screws: thread engagement 3/8" - 1/2" (9 - 13mm).
4. Mounting surface must be level to within 0.5°.
5. Please exercise extreme caution while handling and installing these load cells.

6. Maximum Moment

Rated Capacity	Maximum Moment
0-3 lb.	9 lb.-in.
0-7.5 lb.	22.5 lb.-in.
0-15 lb.	45 lb.-in.
0-25 lb.	125 lb.-in.
0-50 lb.	250 lb.-in.
0-100 lb.	500 lb.-in.
0-150 lb.	500 lb.-in.

7. Applications involving impact/overload forces may require external stops. Request INTERFACE publication IFI #59 for additional information.

PERFORMANCE DATA

Nominal Output—mV/V	3
Input Resistance—Ohms	350 ± 50/-3.5
Output Resistance—Ohms	350 ± 3.5
Recommended Excitation—VDC	10
Non-Linearity—% Rated Output	< ±0.02
Hysteresis—% Rated Output	< ±0.02
Temperature Range, compensated—°F	(-10 to +45°C)
Temperature Effect on Zero—% Rated Output/100°F	(% Rated Output/55.6°C) ±0.15
Zero Balance—% Rated Output	< ±5
Shift Error: Rated Load applied 3 inches (76 mm) for SPI-3 thru 15 and 5 inches (127 mm) for SPI-25 thru 150, from Load Cell centerline—% Rated Load/inch (% Rated Load/25.4 mm)	0.012

SINGLE POINT I LOAD CELL

Model: SPI-7.5

Date: 11-19-1991

Capacity: 7.5

(lbs) Serial: C16380

Output, Compression mV/V: 3.119

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WARRANTY & CERTIFICATION STATEMENT ON OTHER SIDE

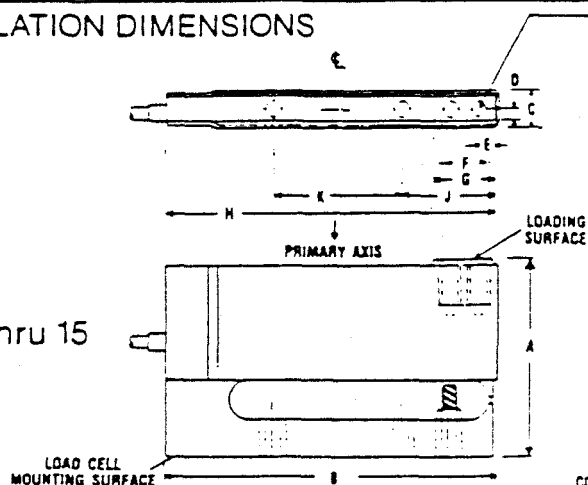
Interface

ADVANCED FORCE MEASUREMENT

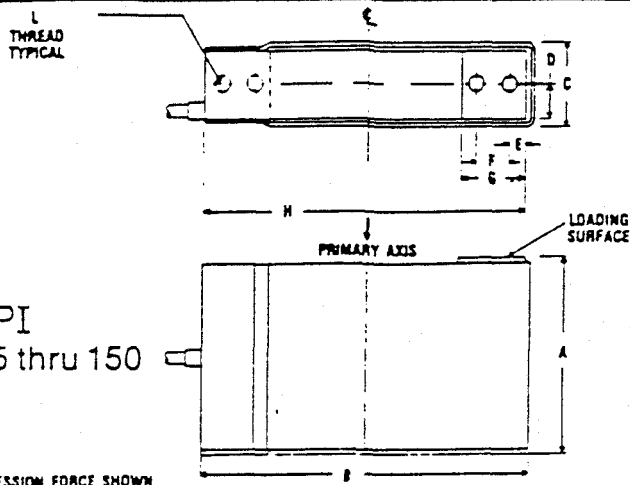
INSTALLATION DIMENSIONS

CALIBRATION CERTIFICATE INSTALLATION INFORMATION

SPI
3 thru 15



SPI
25 thru 150



MODEL		A	B	C	D	E	F	G	H	J	K	L	Torque in-lb
SPI-3	in.	3	5 1/8	1/2	3/16	1/4	.50	1	5	1 1/2	2	10-32	24
	mm	76	130	12.7	4.2	6.4	12.7	25	127	38	51		
SPI-7.5	in.	3	5 1/8	3/4	1/4	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	19	6.4	6.4	12.7	25	127	38	51		
SPI-15	in.	3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	32	12.7	6.4	12.7	25	127	38	51		

MODEL		A	B	C	D*	E*	F*	G*	H	L	Torque in-lb
SPI-25 & 50	in.	3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1/4-28	60
	mm	76	130	32	12.7	6.4	12.7	25	127		
SPI-100	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	60
	mm	76	156	32	12.7	6.4	25	38	152		
SPI-AAB-50 SPI-150	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	90
	mm	76	156	32	12.7	6.4	25	38	152		

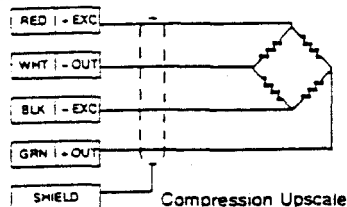
Warning: Exceeding recommended torque levels may damage load cells.

Installation Instructions: Fasten mounting surface to flat surface with two mounting screws. Fasten load receiver to loading surface with two screws.

ELECTRICAL INFORMATION

SPI Series is provided with 4-conductor shielded cable (AWG 28) 5 feet (1.5m) long.

Wiring color code complies with ISA S37.8 "Specifications and Tests for Strain Gage Force Transducers" and SMA Load Cell Terminology.



APPLICATION NOTES

- Single Point I load cells are designed for controlled environmental applications. In general they can be used anywhere a readout instrument is used.
- A moisture resistant coating is applied to protect the SPI Series from high humidity conditions up to and including 95% relative humidity and periodic exposure to condensation. These units are not intended for submerged operation.
- Mounting screws: thread engagement 3/8" - 1/2" (9 - 13mm).
- Mounting surface must be level to within 0.5°.
- Please exercise extreme caution while handling and installing these load cells.

6. Maximum Moment

Rated Capacity	Maximum Moment
0-3 lb.	9 lb.-in.
0-7.5 lb.	22.5 lb.-in.
0-15 lb.	45 lb.-in.
0-25 lb.	125 lb.-in.
0-50 lb.	250 lb.-in.
0-100 lb.	500 lb.-in.
0-150 lb.	500 lb.-in.

- Applications involving impact/overload forces may require external stops. Request INTERFACE publication IFI #59 for additional information.

PERFORMANCE DATA

Nominal Output—mV/V	3
Input Resistance—Ohms	350 ± 50/-3.5
Output Resistance—Ohms	350 ± 3.5
Recommended Excitation—VDC	10
Non-Linearity—% Rated Output	≤ ± 0.02
Hysteresis—% Rated Output	≤ ± 0.02
Temperature Range	
Compensated—°F	(-10 to +45°C) 15 to 115
Temperature Effect on Zero—% Rated Output/100°F	(% Rated Output/55.6°C) ± 0.15
Zero Balance—% Rated Output	≤ ± 5
Shift Error: Rated Load applied 3 inches (76 mm) for SPI-3 thru 15 and 5 inches (127 mm) for SPI-25 thru 150, from Load Cell centerline—% Rated Load/inch (% Rated Load/25.4 mm)	0.012

SINGLE POINT I LOAD CELL

Model: SPI-7.5

Date: 11-19-1991

Capacity: 7.5

(lbs) Serial: C16381

Output, Compression mV/V: 3.161

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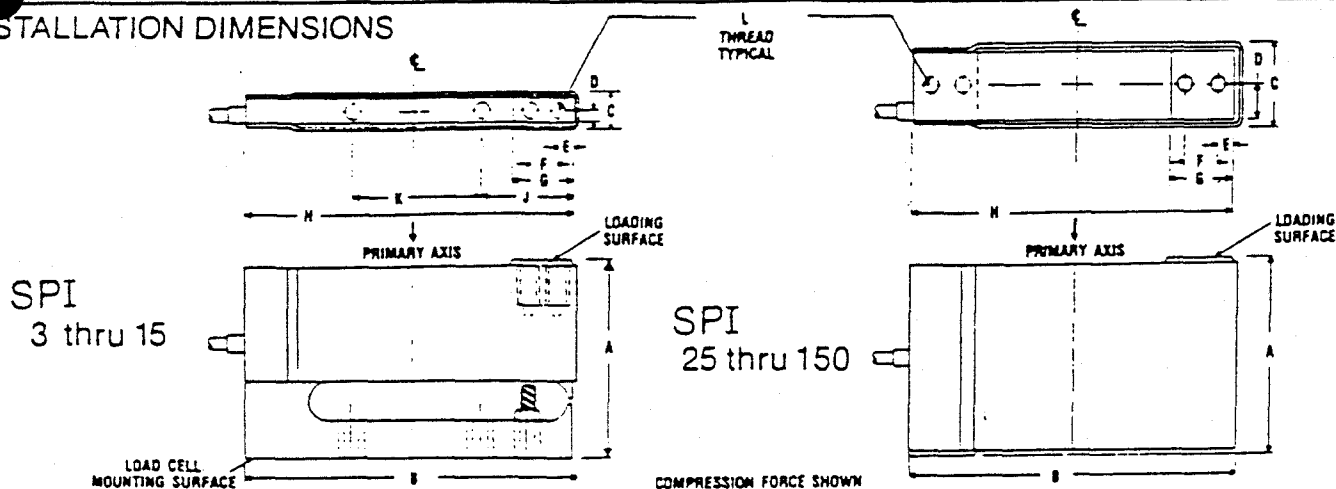
WARRANTY & CERTIFICATION STATEMENT ON OTHER SIDE

interface

CALIBRATION CERTIFICATE INSTALLATION INFORMATION

ADVANCED FORCE MEASUREMENT

INSTALLATION DIMENSIONS



MODEL		A	B	C	D	E	F	G	H	J	K	L	Torque in-lb
SPI-3	in.	3	5/8	1/2	3/16	1/4	.50	1	5	1 1/2	2	10-32	24
	mm	76	130	12.7	4.2	6.4	12.7	25	127	38	51		
SPI-7.5	in.	3	5/8	3/4	1/4	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	19	6.4	6.4	12.7	25	127	38	51		
SPI-15	in.	3	5/8	1 1/4	1/2	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	32	12.7	6.4	12.7	25	127	38	51		

MODEL		A	B	C	D*	E*	F*	G*	H	L	Torque in-lb
SPI-25 & 50	in.	3	5/8	1 1/4	1/2	1/4	.50	1	5	1/4-28	60
	mm	76	130	32	12.7	6.4	12.7	25	127		
SPI-100	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	60
	mm	76	156	32	12.7	6.4	25	38	152		
SPI-AAB-50 SPI-150	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	90
	mm	76	156	32	12.7	6.4	25	38	152		

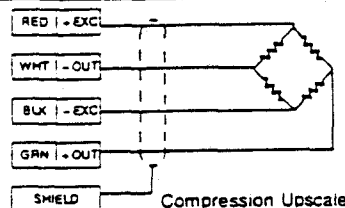
Warning: Exceeding recommended torque levels may damage load cells.

Installation Instructions: Fasten mounting surface to flat surface with two mounting screws. Fasten load receiver to loading surface with two screws.

ELECTRICAL INFORMATION

SPI Series is provided with 4-conductor shielded cable (AWG 28) 5 feet (1.5m) long.

Wiring color code complies with ISA S37.8 "Specifications and Tests for Strain Gage Force Transducers" and SMA Load Cell Terminology.



APPLICATION NOTES

- Single Point I load cells are designed for controlled environmental applications. In general they can be used anywhere a readout instrument is used.
- A moisture resistant coating is applied to protect the SPI Series from high humidity conditions up to and including 95% relative humidity and periodic exposure to condensation. These units are not intended for submerged operation.
- Mounting screws: thread engagement 3/8" - 1/2" (9 - 13mm).
- Mounting surface must be level to within 0.5°.
- Please exercise extreme caution while handling and installing these load cells.

6. Maximum Moment

Rated Capacity	Maximum Moment
0-3 lb.	9 lb-in.
0-7.5 lb.	22.5 lb-in.
0-15 lb.	45 lb-in.
0-25 lb.	125 lb-in.
0-50 lb.	250 lb-in.
0-100 lb.	500 lb-in.
0-150 lb.	500 lb-in.

- Applications involving impact/overload forces may require external stops. Request INTERFACE publication IF1 #59 for additional information.

PERFORMANCE DATA

Nominal Output—mV/V	3
Input Resistance—Ohms	350 ± 50 / - 3.5
Output Resistance—Ohms	350 ± 3.5
Recommended Excitation—VDC	10
Non-Linearity—% Rated Output	< ± 0.02
Hysteresis—% Rated Output	< ± 0.02
Temperature Range,	
Compensated—°F	(-10 to +45°C)
Temperature Effect on Zero—	15 to 115
% Rated Output/100°F	(% Rated Output/55.6°C)
Zero Balance—% Rated Output	± 0.15
Shift Error: Rated Load applied 3 inches (76 mm) for SPI-3	< ± 5
thru 15 and 5 inches (127 mm) for SPI-25 thru 150, from	
Load Cell centerline—	
% Rated Load/inch (% Rated Load/25.4 mm)	0.012

SINGLE POINT I LOAD CELL

Model: SPI-7.5

Date: 11-19-1991

Capacity: 7.5

(lbs) Serial: C16383

Output, Compression mV/V: 3.162

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WARRANTY & CERTIFICATION STATEMENT ON OTHER SIDE

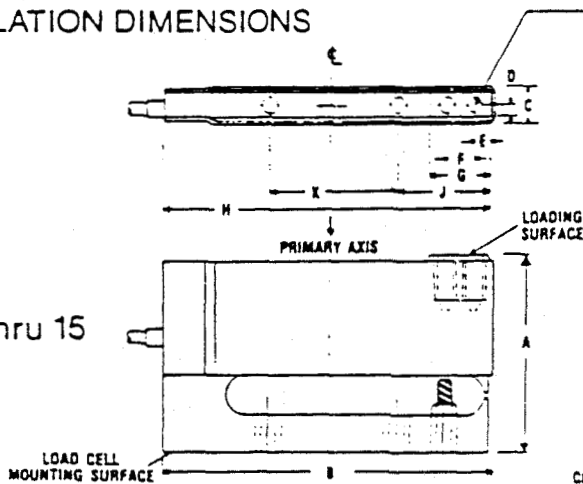
Interface

ADVANCED FORCE MEASUREMENT

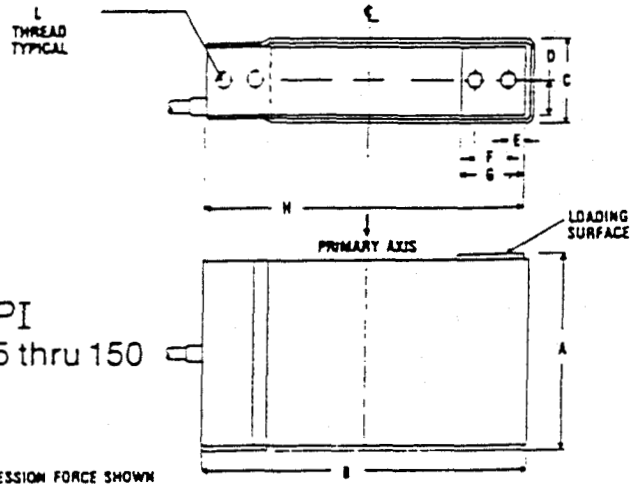
INSTALLATION DIMENSIONS

CALIBRATION CERTIFICATE INSTALLATION INFORMATION

SPI
3 thru 15



SPI
25 thru 150



MODEL	A	B	C	D	E	F	G	H	J	K	L	Torque in-lb
SPI-3	in.	3	5 1/8	1/2	3/16	1/4	.50	1	5	1 1/2	2	10-32
	mm	76	130	12.7	4.2	6.4	12.7	25	127	38	51	
SPI-7.5	in.	3	5 1/8	3/4	1/4	1/4	.50	1	5	1 1/2	2	1/4-28
	mm	76	130	19	6.4	6.4	12.7	25	127	38	51	
SPI-15	in.	3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1 1/2	2	1/4-28
	mm	76	130	32	12.7	6.4	12.7	25	127	38	51	

MODEL	A	B	C	D*	E*	F*	G*	H	L	Torque in-lb
SPI-25 & 50	in.	3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1/4-28
	mm	76	130	32	12.7	6.4	12.7	25	127	
SPI-100	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28
	mm	76	156	32	12.7	6.4	25	38	152	
SPI-AAB-50 SPI-150	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28
	mm	76	156	32	12.7	6.4	25	38	152	

Warning: Exceeding recommended torque levels may damage load cells.

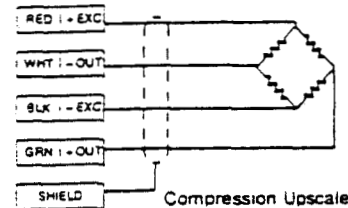
*Typical two places on all SPIs 25 thru 150

Installation Instructions: Fasten mounting surface to flat surface with two mounting screws. Fasten load receiver to loading surface with two screws.

ELECTRICAL INFORMATION

SPI Series is provided with 4-conductor shielded cable (AWG 28) 5 feet (1.5m) long.

Wiring color code complies with ISA S37.8 "Specifications and Tests for Strain Gage Force Transducers" and SMA Load Cell Terminology.



APPLICATION NOTES

- Single Point I load cells are designed for controlled environmental applications. In general they can be used anywhere a readout instrument is used.
- A moisture resistant coating is applied to protect the SPI Series from high humidity conditions up to and including 95% relative humidity and periodic exposure to condensation. These units are not intended for submerged operation.
- Mounting screws: thread engagement 3/8" - 1/2" (9 - 13mm).
- Mounting screws must be level to within 0.5°.
- Please exercise extreme caution while handling and installing these load cells.

6. Maximum Moment

Rated Capacity	Maximum Moment
0-3 lb.	9 lb-in.
0-7.5 lb.	22.5 lb-in.
0-15 lb.	45 lb-in.
0-25 lb.	125 lb-in.
0-50 lb.	250 lb-in.
0-100 lb.	500 lb-in.
0-150 lb.	500 lb-in.

- Applications involving impact/overload forces may require external stops. Request INTERFACE publication IF1 #59 for additional information.

PERFORMANCE DATA

Nominal Output—mV/V	3
Input Resistance—Ohms	350 ± 50/-3.5
Output Resistance—Ohms	350 ± 3.5
Recommended Excitation—VDC	10
Non-Linearity—% Rated Output	< ±0.02
Hysteresis—% Rated Output	< ±0.02
Temperature Range	
Compensated—°F	(-10 to +45°C)
Temperature Effect on Zero—% Rated Output/100°F	(% Rated Output/55.6°C) ±0.15
Zero Balance—% Rated Output	< ±5
Shift Error: Rated Load applied 3 inches (76 mm) for SPI-3 thru 15 and 5 inches (127 mm) for SPI-25 thru 150, from Load Cell centerline—% Rated Load/inch (% Rated Load/25.4 mm)	0.012

SINGLE POINT I LOAD CELL

Model: SPI-7.5

Date: 11-19-1991

Capacity: 7.5

(lbs) Serial: C16386

Output, Compression mV/V: 3.177

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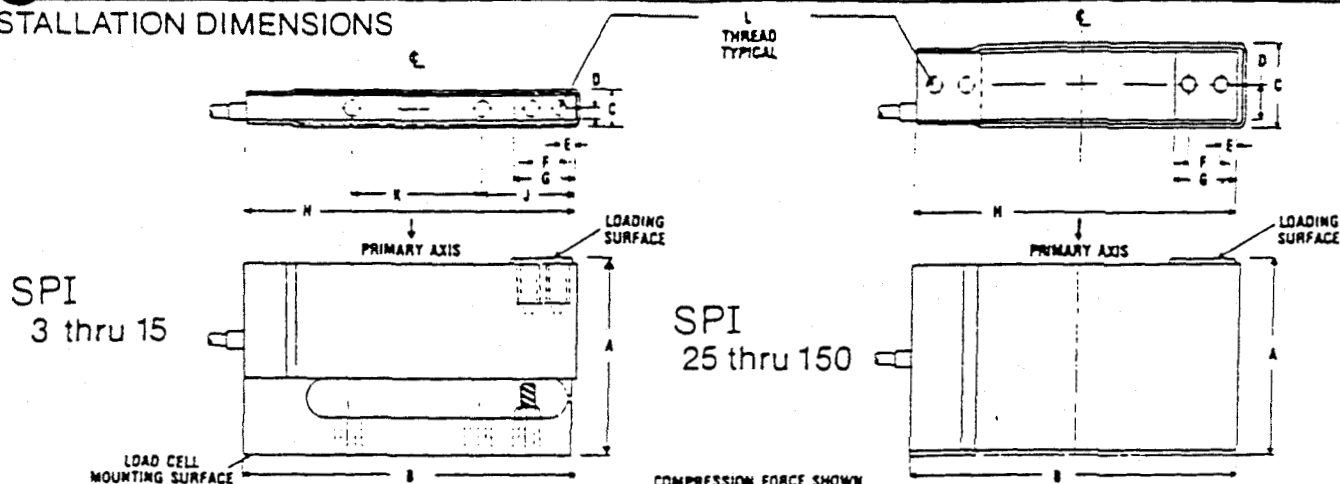
WARRANTY & CERTIFICATION STATEMENT ON OTHER SIDE

Interface

ADVANCED FORCE MEASUREMENT

CALIBRATION CERTIFICATE INSTALLATION INFORMATION

INSTALLATION DIMENSIONS



SPI
3 thru 15

SPI
25 thru 150

MODEL		A	B	C	D	E	F	G	H	J	K	L	Torque in-lb
SPI-3	in.	3	5 1/8	1/2	3/16	1/4	.50	1	5	1 1/2	2	10-32	24
	mm	76	130	12.7	4.2	6.4	12.7	25	127	38	51		
SPI-7.5	in.	3	5 1/8	3/4	1/4	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	19	6.4	6.4	12.7	25	127	38	51		
SPI-15	in.	3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	32	12.7	6.4	12.7	25	127	38	51		

MODEL		A	B	C	D*	E*	F*	G*	H	L	Torque in-lb
SPI-25 & 50	in.	3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1/4-28	60
	mm	76	130	32	12.7	6.4	12.7	25	127		
SPI-100	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	60
	mm	76	156	32	12.7	6.4	25	38	152		
SPI-AAB-50 SPI-150	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	90
	mm	76	156	32	12.7	6.4	25	38	152		

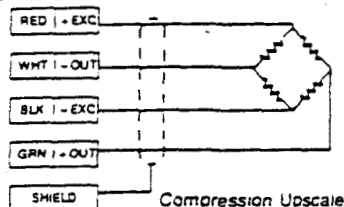
Warning: Exceeding recommended torque levels may damage load cells.

Installation Instructions: Fasten mounting surface to flat surface with two mounting screws. Fasten load receiver to loading surface with two screws.

ELECTRICAL INFORMATION

SPI Series is provided with 4-conductor shielded cable (AWG 28) 5 feet (1.5m) long.

Wiring color code complies with ISA S37.8 "Specifications and Tests for Strain Gage Force Transducers" and SMA Load Cell Terminology.



APPLICATION NOTES

- Single Point I load cells are designed for controlled environmental applications. In general they can be used anywhere a readout instrument is used.
- A moisture resistant coating is applied to protect the SPI Series from high humidity conditions up to and including 95% relative humidity and periodic exposure to condensation. These units are not intended for submerged operation.
- Mounting screws: thread engagement 3/8" - 1/2" (9 - 13mm).
- Mounting surface must be level to within 0.5°.
- Please exercise extreme caution while handling and installing these load cells.

6. Maximum Moment

Rated Capacity	Maximum Moment
0-3 lb.	9 lb.-in.
0-7.5 lb.	22.5 lb.-in.
0-15 lb.	45 lb.-in.
0-25 lb.	125 lb.-in.
0-50 lb.	250 lb.-in.
0-100 lb.	500 lb.-in.
0-150 lb.	500 lb.-in.

- Applications involving impact/overload forces may require external stops. Request INTERFACE publication IF1 #59 for additional information.

PERFORMANCE DATA

Nominal Output—mV/V	3
Input Resistance—Ohms	350 + 50/-3.5
Output Resistance—Ohms	350 ± 3.5
Recommended Excitation—VDC	10
Non-Linearity—% Rated Output	< ±0.02
Hysteresis—% Rated Output	< ±0.02
Temperature Range	
Compensated—°F	(-10 to +45°C) 15 to 115
Temperature Effect on Zero—% Rated Output/100°F	(% Rated Output/55.6°C) ±0.15
Zero Balance—% Rated Output	< ±5
Shift Error: Rated Load applied 3 inches (76 mm) for SPI-3 thru 15 and 5 inches (127 mm) for SPI-25 thru 150, from Load Cell centerline—% Rated Load/inch (% Rated Load/25.4 mm)	0.012

SINGLE POINT I LOAD CELL

Model: SPI-7.5

Date: 11-19-1991

Capacity: 7.5

(lbs) Serial: C16387

Output, Compression mV/V: 3.287

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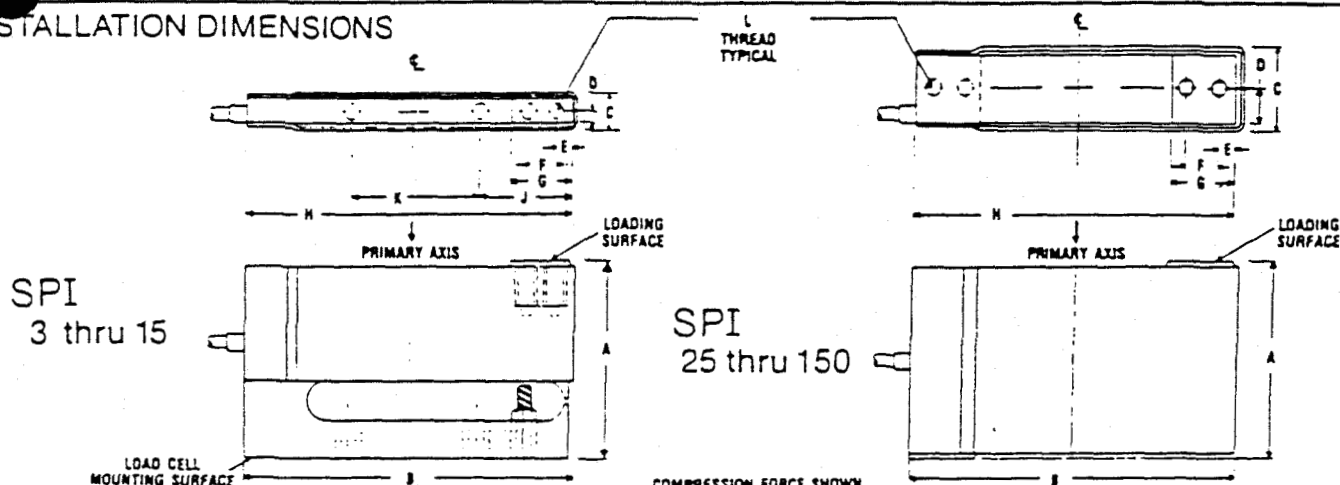
WARRANTY & CERTIFICATION STATEMENT ON OTHER SIDE

Interface

ADVANCED FORCE MEASUREMENT

INSTALLATION DIMENSIONS

CALIBRATION CERTIFICATE INSTALLATION INFORMATION



MODEL		A	B	C	D	E	F	G	H	J	K	L	Torque in.-lb.
SPI-3	in.	3	5 1/8	1/2	3/16	1/4	.50	1	5	1 1/2	2	10-32	24
	mm	76	130	12.7	4.2	6.4	12.7	25	127	38	51		
SPI-7.5	in.	3	5 1/8	3/4	1/4	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	19	6.4	6.4	12.7	25	127	38	51		
SPI-15	in.	3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm	76	130	32	12.7	6.4	12.7	25	127	38	51		

MODEL		A	B	C	D*	E*	F*	G*	H	L	Torque in.-lb.
SPI-25 & 50	in.	3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1/4-28	60
	mm	76	130	32	12.7	6.4	12.7	25	127		
SPI-100	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	60
	mm	76	156	32	12.7	6.4	25	38	152		
SPI-AAB-50 SPI-150	in.	3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	90
	mm	76	156	32	12.7	6.4	25	38	152		

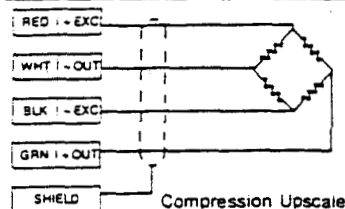
Warning: Exceeding recommended torque levels may damage load cells.

Installation Instructions: Fasten mounting surface to flat surface with two mounting screws. Fasten load receiver to loading surface with two screws.

ELECTRICAL INFORMATION

SPI Series is provided with 4-conductor shielded cable (AWG 28) 5 feet (1.5m) long.

Wiring color code complies with ISA S37.8 "Specifications and Tests for Strain Gage Force Transducers" and SMA Load Cell Terminology.



APPLICATION NOTES

- Single Point I load cells are designed for controlled environmental applications. In general they can be used anywhere a readout instrument is used.
- A moisture resistant coating is applied to protect the SPI Series from high humidity conditions up to and including 95% relative humidity and periodic exposure to condensation. These units are not intended for submerged operation.
- Mounting screws: thread engagement 3/8" - 1/2" (9 - 13mm).
- Mounting surface must be level to within 0.5°.
- Please exercise extreme caution while handling and installing these load cells.

6. Maximum Moment

Rated Capacity	Maximum Moment
0-3 lb.	9 lb.-in.
0-7.5 lb.	22.5 lb.-in.
0-15 lb.	45 lb.-in.
0-25 lb.	125 lb.-in.
0-50 lb.	250 lb.-in.
0-100 lb.	500 lb.-in.
0-150 lb.	500 lb.-in.

- Applications involving impact/overload forces may require external stops. Request INTERFACE publication IFI #59 for additional information.

PERFORMANCE DATA

Nominal Output—mV/V	3
Input Resistance—Ohms	350 + 50/-3.5
Output Resistance—Ohms	350 ± 3.5
Recommended Excitation—VDC	10
Non-Linearity—% Rated Output	< ±0.02
Hysteresis—% Rated Output	< ±0.02
Temperature Range,	
Compensated—°F	(-10 to +45°C) 15 to 115
Temperature Effect on Zero—	
% Rated Output/V100°F	(% Rated Output/V55.6°C) ±0.15
Zero Balance—% Rated Output	< ±5
Shift Error: Rated Load applied 3 inches (76 mm) for SPI-3	
thru 15 and 5 inches (127 mm) for SPI-25 thru 150, from	
Load Cell centerline—	
% Rated Load/inch (% Rated Load/25.4 mm)	0.012

SINGLE POINT I LOAD CELL

Model: SPI-7.5

Date: 09-13-1991

Capacity: 7.5

(lbs) Serial: C16396

Output, Compression mV/V: 3.164

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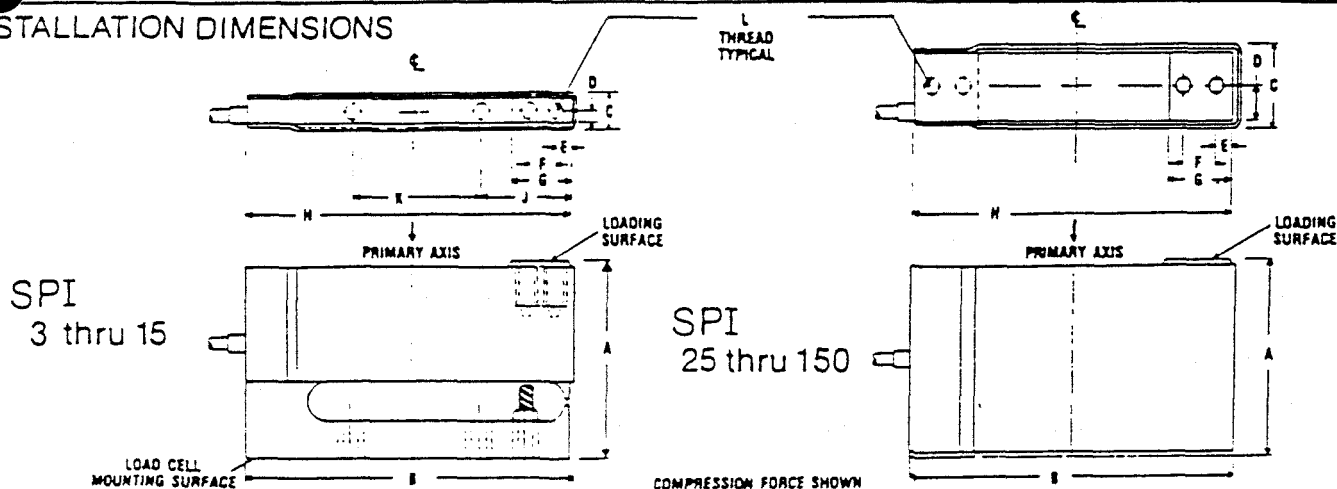
WARRANTY & CERTIFICATION STATEMENT ON OTHER SIDE

Interface

ADVANCED FORCE MEASUREMENT

CALIBRATION CERTIFICATE INSTALLATION INFORMATION

INSTALLATION DIMENSIONS



MODEL	A	B	C	D	E	F	G	H	J	K	L	Torque in-lb
SPI-3	in. 3	5 1/8	1/2	3/16	1/4	.50	1	5	1 1/2	2	10-32	24
	mm 76	130	12.7	4.2	6.4	12.7	25	127	38	51		
SPI-7.5	in. 3	5 1/8	3/4	1/4	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm 76	130	19	6.4	6.4	12.7	25	127	38	51		
SPI-15	in. 3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1 1/2	2	1/4-28	36
	mm 76	130	32	12.7	6.4	12.7	25	127	38	51		

MODEL	A	B	C	D*	E*	F*	G*	H	L	Torque in-lb
SPI-25 & 50	in. 3	5 1/8	1 1/4	1/2	1/4	.50	1	5	1/4-28	60
	mm 76	130	32	12.7	6.4	12.7	25	127		
SPI-100	in. 3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	60
	mm 76	156	32	12.7	6.4	25	38	152		
SPI-AAB-50 SPI-150	in. 3	6 1/8	1 1/4	1/2	1/4	1.00	1.5	6	1/4-28	90
	mm 76	156	32	12.7	6.4	25	38	152		

*Warning: Exceeding recommended torque levels may damage load cells.

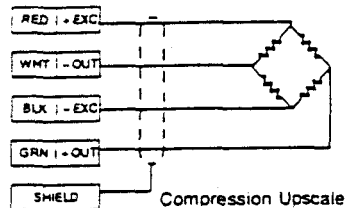
*Typical two pieces on all SPIs 25 thru 150

Installation Instructions: Fasten mounting surface to flat surface with two mounting screws. Fasten load receiver to loading surface with two screws.

ELECTRICAL INFORMATION

SPI Series is provided with 4-conductor shielded cable (AWG 28) 5 feet (1.5m) long.

Wiring color code complies with ISA S37.8 "Specifications and Tests for Strain Gage Force Transducers" and SMA Load Cell Terminology.



APPLICATION NOTES

1. Single Point I load cells are designed for controlled environmental applications. In general they can be used anywhere a readout instrument is used.
2. A moisture resistant coating is applied to protect the SPI Series from high humidity conditions up to and including 95% relative humidity and periodic exposure to condensation. These units are not intended for submerged operation.
3. Mounting screws: thread engagement 3/8" - 1/2" (9 - 13mm).
4. Mounting surface must be level to within 0.5°.
5. Please exercise extreme caution while handling and installing these load cells.

6. Maximum Moment

Rated Capacity	Maximum Moment
0-3 lb.	9 lb-in.
0-7.5 lb.	22.5 lb-in.
0-15 lb.	45 lb-in.
0-25 lb.	125 lb-in.
0-50 lb.	250 lb-in.
0-100 lb.	500 lb-in.
0-150 lb.	500 lb-in.

7. Applications involving impact/overload forces may require external stops. Request INTERFACE publication IF1 #59 for additional information.

PERFORMANCE DATA

Nominal Output—mV/V	3
Input Resistance—Ohms	350 ± 50/-3.5
Output Resistance—Ohms	350 ± 3.5
Recommended Excitation—VDC	10
Non-Linearity—% Rated Output	< ±0.02
Hysteresis—% Rated Output	< ±0.02
Temperature Range, compensated—°F	(-10 to +45°C)
Temperature Effect on Zero—% Rated Output/100°F	(% Rated Output/55.6°C) ±0.15
Zero Balance—% Rated Output	< ±5
Shift Error: Rated Load applied 3 inches (76 mm) for SPI-3 thru 15 and 5 inches (127 mm) for SPI-25 thru 150, from Load Cell centerline—% Rated Load/inch (% Rated Load/25.4 mm)	0.012

SINGLE POINT I LOAD CELL

Model: SPI-7.5

Date: 11-19-1991

Capacity: 7.5

(lbs) Serial: C16398

Output, Compression mV/V: 3.160

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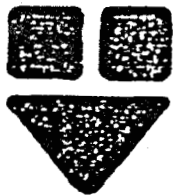
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Telex: 825-882

WARRANTY & CERTIFICATION STATEMENT ON OTHER SIDE

Appendix V

Manufacturer's Information for Tension Soil Solution Sampler



PRENART EQUIPMENT ApS
Buen 14 2000 Frederiksberg, Denmark

Telefon 31 74 16 64
Giro 1 51 10 76

The PRENART soil water sampler is now available with 3 different pore sizes.

No RING X

Large : Pore size 10 μm .

Most applicable for sampling of bigger water volumes during shorter periods.

Continuous vacuum systems preferred.

1 RING

X Medium : Pore size 5 μm .

Applicable in most unspecified cases.

Small : Pore size 3 μm .

Most applicable for sampling of smaller water volumes during longer periods. Continuous vacuum systems not needed for sampling periods less than 3 weeks.

You have received the marked type.

To ensure good contact between the soil pores and the pores of the sampler, the following installation procedure is recommended. Make a thin slurry (suspension) with soil from the coming installation depth (water:soil = 10:1). Alternatively quartz powder can be used for the slurry. Put the sampler into the slurry with vacuum on for 15 minutes. This procedure will fill the biggest pores of the sampler with small soil particles and thereby ensure good capillary contact. The sampler is now ready for installation.



PRENART EQUIPMENT ApS
Buen 14 2000 Frederiksberg, Denmark

Telefon 31 74 16 64
Giro 1 51 10 76

Installation procedure for the PRENART soil water sampler

Materials

PRENART soil water sampler
PRENART collecting bottle with screw cap
PRENART steel rod, diameter 20 mm
Plastic or metal pipe, max diameter 20 mm
Plastic pipe with funnel
Water
1-2 L beaker
String
Quartz powder

Installation

1. New PRENART soil water samplers are already rinsed in HCl and deionized water, ready for installation.
2. Mix a thin slurry in the beaker of water with quartz powder or soil from the comming installation depth.
3. Place the PRENART soil water sampler in the slurry and put 0.5 bar vacuum on for 10-15 min. By this procedure the biggest pores in the sampler are filled with fine soil or quartz powder to ensure a tight capillary contact with the soil.
4. With the PRENART steel rod a hole is made in an oblique angle in the soil to the wanted depth for installation. This procedure ensures that the soil directly over the sampler is left undisturbed.
5. Mix a thicker slurry of water and quartz powder or sieved soil and pour it down to the bottom of the hole through the plastic pipe with the funnel. This procedure ensures that soil moisture can move readily from the pores of the soil through the pores of the PRENART soil water sampler.
6. Tie the string to the top-fitting of the sampler, in case you want to take it up again.
7. The tube from the sampler is put through the plastic or metal pipe, and the sampler is pushed down in the hole with the pipe.
8. Backfill hole with slurry or native soil free of pebbles and rocks.
9. The tubing is connected to the collecting bottle and vacuum is created in the bottle.
10. Do not use the first samples for chemical analyses. The system needs a little time to stabilize.

Eksemplar til afsendelses / udførselsland

1000

54:10

Faktura vedlagt

200991 :

54 : 100 on ratio

B REGNSKABSMÆSSIGE OPLYSNINGER

C AFGANGSTOLDSTED

53 Besiggningshistorisk (og land)



PRENART
EQUIPMENT ApS

Woodward-Clyde
4582 South Ulster Street Parkway
Suite 1200
Denver, Colorado 80237
U.S.A.

Att.: Linda Fulton

FAKTURA/INVOICE: 7165

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Den Danske Bank
S.W.I.F.T.: DABADKKK
Account No.
4263-4263-132092

20th Sept. 1991

ref.: purchase order no. 1506

50 PRENART soil water sampler (medium), unit price \$71.54
50 PRENART soil water sampler (large), unit price \$71.54

Carriage, insurance, custom

\$ 3,577.00
\$ 3,577.00
\$ 7,154.00
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\$ 7,204.00
=====

Items to be shipped by air mail in week no. 39.
Payment before 20th Oct. 1991.

Appendix VI

Pre-Installation Calibration of TDR Probes

Appendix V| Pre-Installation Calibration of Time Domain Reflectometry (TDR) Probes

A control volume is used in the calibration of the TDR probe to obtain a known volume from which soil densities (gm/cm^3) are calculated at varying moisture content.

- To obtain a control volume, use a pan so that a single TDR probe (two wave guides attached to twin cable leads) can be surrounded with at least 2 inches (5 cm) of soil.
- Draw a line, using a water proof pen, onto the side of the control volume pan 2 inches (5 cm) up from the bottom.
- Using an electronic scale (e.g. Mettler), measure and record the dry pan weight.
- Fill the pan to the control volume line with water. Weigh and record this value.
- Since water has a density of $1 \text{ g}/\text{cm}^3$, the volume of the pan at the control volume mark (cm^3) is obtained by subtracting the dry pan weight from the weight obtained when water is added. This will be the control volume used for calibration (cm^3). Note: $1 \text{ cm}^3 = 1 \text{ ml}$.

A baseline or starting point of the amount of dry soil is needed so that the amount of water in the soil can easily be measured.

- Select a soil which does not contain a large amount of organic material. Using a heat lamp, oven, or the sun, dry approximately 5 kilograms (10 pounds) of the soil, removing all residual moisture. Be careful not to overdry the soil as overheating of the soil will result in destroying organics in the soil changing its composition.
- Using a No. 10 sieve, screen enough dry soil to fill the control volume of the pan. Periodically, drop the pan to the floor or table from a height of 6 inches (7.5 cm), while filling to achieve proper settling of the soil (tamping). Measure and record this weight.
- To determine if the soil is dry, leave the soil on the scale for approximately 5 minutes.
- If the weight remains the same or increases (moisture gain), the soil is to be considered dry and the baseline dry weight can be established. If the weight of the soil decreases (moisture loss), the soil must be dried further.
- Place the control volume pan onto the scale. Record this weight. Remove the pan from the scale.
- Into the pan, place one-half of a control volume with dry soil. Weigh and record this value.
- Place the TDR probe onto the soil. Measure and record this weight. Remove the pan from

the scale. Subtract the weight of the control volume pan with soil from this value to calculate the weight of the probe. Record this value.

- Fill the pan to the control volume line with dry soil and tamp it down.
- Place the pan onto the scale, weigh and record this value.
- Subtract the weight of the probe and the pan weight from the total weight to obtain the weight of the dry soil (gm). This will be the baseline weight of dry soil.
- The density of dry soil (gm/cm^3) is obtained by dividing the baseline weight of dry soil (gm) by the control volume (cm^3).

The addition of water is done in specified increments until saturation is obtained. Saturation shall be considered to be the point when a saturated paste is achieved. A saturated paste is a soil that contains enough water such that when a smooth rod (e.g., glass) is put in and removed, very little soil remains on the rod.

- Place the pan containing the TDR probe onto the scale, add approximately 100 g (100 cm^3) of water and record the weight. Add the water into the middle of the soil to avoid splashing the water onto the sides of the pan.
- Remove the pan from the scale and place the soil from the control volume pan into a larger mixing pan being careful not to spill any of the soil or water.
- Mix the soil and water thoroughly to achieve a homogeneous mixture.
- Place one-half of the mixture back into the control volume pan, place the TDR probe onto the soil, then add the remainder of the mixture.
- Tamp the mixture down to the control volume mark and level with a straight edge, if necessary. Do not remove any soil after leveling, just tamp down the soil a little harder until the mixture reaches the control volume mark. The mixture will only exceed the mark when all air voids are filled with water and saturation is reached.
- Place the pan onto the scale, measure and record the weight. The weight should be within $\pm 2 \text{ gm}$ of the premixed weight.
- Turn on the data logger, measure and record the soil moisture. (See the appropriate instruction manual for details).
- Repeat this procedure of adding water and weighing until the soil reaches 40% water volume. Mixing should be performed in the control volume pan after the initial water

addition. Transferring the mixture to a second pan at this time may result in unacceptable material loss.

- Add water to the mixture in small increments (e.g., 50 gm) recording the weights as you go. After each addition, place a smooth rod (i.e., glass) into the soil, mix and remove. If little or no soil comes off the rod, the saturated paste has been achieved and water addition stops.

The following steps and equations will provide the necessary information to calculate the volumetric moisture content of soils.

- The control volume (cm^3) is calculated in 5.2.1 using water as the medium.
- The density of dry soil (gm/cm^3) is calculated using the dry soil weight obtained in 5.2.2 and dividing that number by the control volume.
- The dry soil volume (cm^3) is calculated by dividing the density of the dry soil (gm/cm^3) by the baseline weight of the dry soil (gm).
- Volumetric soil moisture content (% M) is calculated by adding the dry control volume (cm^3) to the total amount of water added, then dividing this number into the total amount of water added.

$$\% M = \frac{x}{(x + y)} \quad (1)$$

where: x = total volume of water added (cm^3)
 y = dry control volume of soil (cm^3)

- A mathematical regression is done on the data using the percent moisture content calculated gravimetrically, % water by weight (scale), verses the TDR reading, % water by volume (TDR). Graphing the data will aid in visualizing the results. This analysis will be conducted using a computer software spreadsheet program (e.g., Lotus 1-2-3) so that data can be easily mathematically regressed and graphed.

Calibration of Campbell TDR Probe (#1) with 1" of soil
 William Fronczak - Woodward-Clyde
 03-31-92

Weight of Pan = 305.24 g **
 Weight of Probe = 95.44 g **

Run #	Weight Total	Weight soil	Weight Water	Bulk Density	% water weight	% water volume	% water TDR
1	4817.34	4416.66	0	1.31	0.00	0.00	0
2	4915.02	4514.34	97.68	1.34	2.16	2.90	0
3	5024	4623.32	206.66	1.37	4.47	6.13	2.4
4	5122.07	4721.39	304.73	1.40	6.45	9.04	4.9
5	5273.57	4872.89	456.23	1.45	9.36	13.54	10.3
6	5379.19	4978.51	561.85	1.48	11.29	16.67	13.8
7	5481.42	5080.74	664.08	1.51	13.07	19.71	16.8
8	5589.36	5188.68	772.02	1.54	14.88	22.91	21.7
9	5688.84	5288.16	871.5	1.81	16.48	29.80	28.3
10	5794.96	5394.28	977.62	1.84	18.12	33.43	32.3
11	5894.87	5494.19	1077.53	1.88	19.61	36.84	35.1
12	6028.8	5628.12	1211.46	1.92	21.53	41.42	37.3

Regression Output:			volume *	Regression Output:			weight *
Constant			-2.53689	Constant			-5.17828
Std Err of Y Est			1.38515	Std Err of Y Est			2.80854
R Squared			0.99093	R Squared			0.96273
No. of Observations			12	No. of Observations			12
Degrees of Freedom			10	Degrees of Freedom			10
X Coefficient(s)	1.00404284			X Coefficient(s)	1.928592		
Std Err of Coef.	0.03037009			Std Err of Coef.	0.120002		

* % water by volume

* % water by weight

** These values are subtracted from the total weight to get the soil weight

Calibration of Campbell TDR Probe #10
 William Fronczak - Woodward-Clyde
 04-20-92

Weight of Pan = 304.63 g **
 Weight of Probe = 106.87 g **

Run #	Weight Total	Weight soil	Weight Water	Bulk Density	% water weight	% water volume	% water TDR
1	4751.6	4340.10	0.00	1.29	0.00	0.00	0
2	4899.31	4487.81	147.71	1.33	3.29	4.38	0.144
3	5038.5	4627.00	286.90	1.37	6.20	8.51	3.68
4	5101.3	4689.80	349.70	1.39	7.46	10.38	7.01
5	5251.33	4839.83	499.73	1.44	10.33	14.83	13.35
6	5364.8	4953.30	613.20	1.47	12.38	18.20	16.83
7	5530.2	5118.70	778.60	1.75	15.21	26.62	26.4
8	5630	5218.50	878.40	1.78	16.83	30.03	31.6
9	5710.7	5299.20	959.10	1.81	18.10	32.79	33.08
10	5790.23	5378.73	1038.63	1.84	19.31	35.51	36.42
11	5854.05	5442.55	1102.45	1.86	20.26	37.69	38.78

Regression Output:		* volume	Regression Output:		* weight
Constant		-3.4852	Constant		-6.3596
Std Err of Y Est		1.5939	Std Err of Y Est		3.0565
R Squared		0.9898	R Squared		0.9624
No. of Observations		11.0000	No. of Observations		11.0000
Degrees of Freedom		9.0000	Degrees of Freedom		9.0000
X Coefficient(s)	1.1218		X Coefficient(s)	2.1432	
Std Err of Coef.	0.0380		Std Err of Coef.	0.1412	

** These values are subtracted from the total weight to get the soil weight

Calibration of Campbell TDR Probe #100
 William Fronczak - Woodward-Clyde
 05-19-92

Weight of Pan = 308.79 g **
 Weight of Probe = 109.17 g **

Run #	Weight Total	Weight soil	Weight Water	Bulk Density	% water weight	% water volume	% water TDR
1	4728.9	4310.94	0.00	1.28	0.00	0.00	0
2	5017.6	4599.64	288.70	1.37	6.28	8.57	7.06
3	5299.5	4881.54	570.60	1.45	11.69	16.93	18.41
4	5564.4	5146.44	835.50	1.53	16.23	24.80	31.78
5	5670.3	5252.34	941.40	1.56	17.92	27.94	35.22
6	5756.8	5338.84	1027.90	1.58	19.25	30.51	36.75

Regression Output:		* volume	Regression Output:		* weight
Constant		-1.8576	Constant		-2.7698
Std Err of Y Est		1.9269	Std Err of Y Est		2.6341
R Squared		0.9877	R Squared		0.9770
No. of Observations		6.0000	No. of Observations		6.0000
Degrees of Freedom		4.0000	Degrees of Freedom		4.0000
X Coefficient(s)	1.2908		X Coefficient(s)	2.0432	
Std Err of Coef.	0.0720		Std Err of Coef.	0.1567	

Calibration of Campbell TDR Probe #101
 William Fronczak - Woodward-Clyde
 05-19-92

Weight of Pan = 308.79 g **
 Weight of Probe = 101.18 g **

Run #	Weight Total	Weight soil	Weight Water	Bulk Density	% water weight	% water volume	% water TDR
1	4720.6	4310.63	0.00	1.28	0.00	0.00	0
2	5012.05	4602.08	291.45	1.37	6.33	8.65	5.91
3	5291.85	4881.88	571.25	1.45	11.70	16.95	16.08
4	5556.4	5146.43	835.80	1.53	16.24	24.81	32.25
5	5668.5	5258.53	947.90	1.56	18.03	28.13	36.21
6	5752.74	5342.77	1032.14	1.59	19.32	30.63	36.72

Regression Output:		* volume	Regression Output:		* weight
Constant		-2.8674	Constant		-3.7454
Std Err of Y Est		3.0448	Std Err of Y Est		3.7986
R Squared		0.9714	R Squared		0.9555
No. of Observations		6.0000	No. of Observations		6.0000
Degrees of Freedom		4.0000	Degrees of Freedom		4.0000
X Coefficient(s)	1.3224		X Coefficient(s)	2.0894	
Std Err of Coef.	0.1134		Std Err of Coef.	0.2254	

** These values are subtracted from the total weight to get the soil weight

Calibration of Campbell TDR Probe #110
 William Fronczak - Woodward-Clyde
 05-20-92

Weight of Pan = 308.4 g **
 Weight of Probe = 100.26 g **

Run #	Weight Total	Weight soil	Weight Water	Bulk Density	% water weight	% water volume	% water TDR
1	4717.76	4309.10	0.00	1.28	0.00	0.00	0
2	4993.35	4584.69	275.59	1.36	6.01	8.18	6.3
3	5272.56	4863.90	554.80	1.44	11.41	16.47	14.49
4	5483.95	5075.29	766.19	1.51	15.10	22.74	29.27
5	5664.45	5255.79	946.69	1.56	18.01	28.10	36.11
6	5776.7	5368.04	1058.94	1.59	19.73	31.43	36.98

Regression Output:		* volume	Regression Output:		* weight
Constant		-2.4587	Constant		-3.4142
Std Err of Y Est		3.1636	Std Err of Y Est		3.8151
R Squared		0.9680	R Squared		0.9534
No. of Observations		6.0000	No. of Observations		6.0000
Degrees of Freedom		4.0000	Degrees of Freedom		4.0000
X Coefficient(s)	1.2899		X Coefficient(s)	2.0445	
Std Err of Coef.	0.1173		Std Err of Coef.	0.2259	

** These values are subtracted from the total weight to get the soil weight

Calibration of Campbell TDR Probe #144
 William Fronczak - Woodward-Clyde
 06-05-92

Weight of Pan = 316.57 g **
 Weight of Probe = 103.11 g **

Run #	Weight Total	Weight soil	Weight Water	Bulk Density	% water weight	% water volume	% water TDR
1	4625.32	4205.64	0.00	1.25	0.00	0.00	0
2	4863.78	4444.10	238.46	1.32	5.37	7.08	7.18
3	5289.1	4869.42	663.78	1.45	13.63	19.70	20.29
4	5600.1	5180.42	974.78	1.54	18.82	28.93	34.54
5	5671.9	5252.22	1046.58	1.56	19.93	31.06	34.54

Regression Output:		* volume	Regression Output:		* weight
Constant		-0.7137	Constant		-1.4851
Std Err of Y Est		1.5724	Std Err of Y Est		2.2722
R Squared		0.9925	R Squared		0.9843
No. of Observations		5.0000	No. of Observations		5.0000
Degrees of Freedom		3.0000	Degrees of Freedom		3.0000
X Coefficient(s)	1.1539		X Coefficient(s)	1.8007	
Std Err of Coef.	0.0580		Std Err of Coef.	0.1314	

** These values are subtracted from the total weight to get the soil weight

Appendix VII
Tensiometer SOP

FIELD USE OF TENSIO METERS

EG&G ROCKY FLATS PLANT
EMAD MANUAL SOP

Manual:
Procedure No.
Page:
Effective Date:
Organization:

5-21200-OPS

GT.27

1 of 21¹⁷

June 20, 1992

Category 2

Environmental Management

TITLE:
FIELD USE OF
TENSIO METERS

Approved By:

(Name of Approver)

(Date)

1.0 TABLE OF CONTENTS

1.0	TABLE OF CONTENTS	1
2.0	PURPOSE AND SCOPE	3
3.0	RESPONSIBILITIES AND QUALIFICATIONS	3
4.0	REFERENCES	4
4.1	SOURCE REFERENCES	4
4.2	INTERNAL REFERENCES	4
5.0	DESIGN FEATURES AND PRINCIPLES OF OPERATION	5
6.0	FIELD USE OF TENSIO METERS	7
6.1	MATERIALS AND EQUIPMENT	7
6.2	PROCEDURES	8
6.2.1	Site Preparation.....	8
6.2.2	Installation	9
6.2.3	Maintenance	10
6.2.4	Automatic Data Collection Using a Tensicorder ...	11
6.2.5	Field Data Collection	13

FIELD USE OF TENSIOLOGERS

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EG&G ROCKY FLATS PLANT
EMAD MANUAL SOP

Manual:
Procedure No.
Page:
Effective Date:
Organization:

5-21200-OPS

GT.27

2 of 21

June 20, 1992

Category 2

Environmental Management

6.2.6 Data Transfer from the Tensicorder 14

6.2.7 Data Analysis 15

7.0 DECONTAMINATION 15

8.0 DOCUMENTATION 16

LIST OF FIGURES

FIGURE GT.26.1, Tensiometer 5

FIGURE GT.26.2, Field Arrangement 7

ATTACHED

SAMPLE FORM FOR TENSIOLOGER WATER LEVEL DATA COLLECTION

FIELD USE OF TENSIOMETERS

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EG&G ROCKY FLATS PLANT
EMAD MANUAL SOP

Manual:
Procedure No.
Page:
Effective Date:
Organization:

5-21200-OPS

GT.27

3 of 21

June 20, 1992

Category 2

Environmental Management

2.0 PURPOSE AND SCOPE

This standard operating procedure (SOP) describes methods that will be used at the Rocky Flats Plant (RFP) to determine the matric potential of soils using Soil Measurement Systems (SMS) tensiometers.

Matric potential is a pressure potential that arises from the interaction of water with the matrix of solid particles in which it is embedded. It is the energy per unit volume of water required to transfer an infinitesimal quantity of water from a reference pool of soil water at the elevation of the soil to the point of interest in the soil at reference air pressure.

Matric potential testing will be performed at various soil depths adjacent to trenches containing soil solution measurement apparatus as described in SOP GT.20, Procedure for Soil Interstitial Water Sampling and Sampler Installation. All activities will be conducted in accordance with the Health And Safety Plan (HSP) for these activities.

3.0 RESPONSIBILITIES AND QUALIFICATIONS

Personnel performing matric potential testing will be soil scientists, hydrologists, geologists, geotechnical engineers, or technicians with the appropriate amount of applicable field experience or on-the-job training under the supervision of a qualified person.

FIELD USE OF TENSIOMETERS

DRAFT

EG&G ROCKY FLATS PLANT
EMAD MANUAL SOP:

Manual:
Procedure No.
Page:
Effective Date:
Organization:

5-21200-OPS
GT.27

4 of 21,7 *5-21*

June 20, 1992

Category 2

Environmental Management

4.0 REFERENCES

4.1 SOURCE REFERENCES

The following is a list of references reviewed prior to the writing of this procedure:

Soil Measurement Systems; Installation and Maintenance of SMS Tensiometers, unpublished manual, 1992.

Soil Measurement Systems; Tensicorder Users Manual, 1992.

Jury, W.A., W.R. Gardner and W.H. Gardner. 1991. Soil Physics. 5th ed. John Wiley and Sons, Inc. NY

Marshall T.J. and J.W. Holmes. 1979. Soil Physics. Cambridge University Press, Cambridge, G.B.

Warrick A.W. 1990. Nature and Dynamics of Soil Water; in Irrigation of Agricultural Crops--Agronomy Monograph no. 30. pp. 69-92

Wierenga, P.J. unpubl. Interpretation of Tensiometer Readings.

4.2 INTERNAL REFERENCES

Related SOPs cross-referenced by this SOP are:

- SOP FO.03, General Equipment Decontamination.
- SOP FO.06, Handling of Personal Protective Equipment.
- SOP FO.07, Handling of Decontamination Water and Wash Water.
- SOP FO.14, Field Data Management.
- SOP GT.20, Procedures for Soil Interstitial Water Sampling and Sampler Installation.
- SOP GT.26, Determining Hydrologic Conductivity Using a Tension Infiltrometer.

FIELD USE OF TENSIOMETERS

DRAFT

EG&G ROCKY FLATS PLANT
EMAD MANUAL SOP

Manual:
Procedure No.
Page:
Effective Date:
Organization:

5-21200-OPS
GT.27

5 of 21/7

June 20, 1992

Category 2

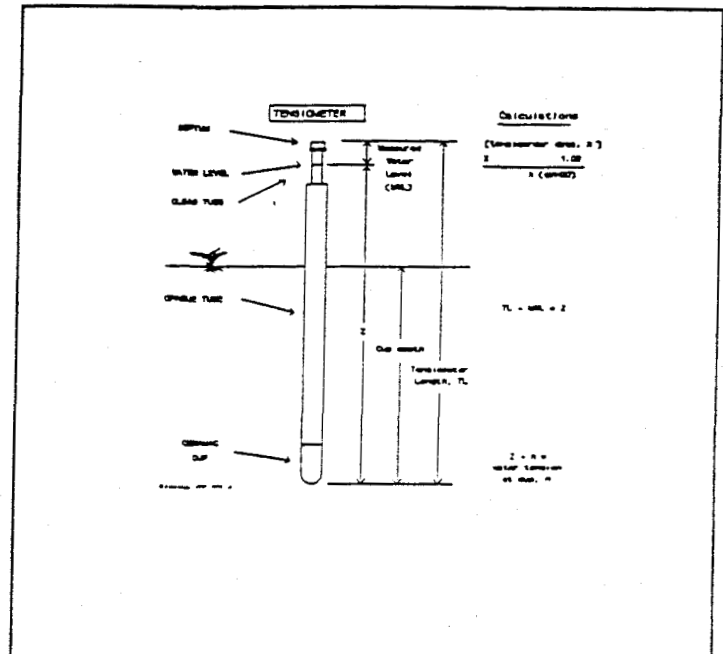
Environmental Management

5.0 DESIGN FEATURES AND PRINCIPLES OF OPERATION

Tensiometers are used to measure soil water potential (or matric potential) in unsaturated soils. Matric potential is an element of total soil water potential. Soil water potential is equivalent to the amount of work that must be done against some combination of forces (including matric potential) to move water from a standard state to the point under consideration.

The standard state is the state of pure, free water at a reference pressure P_0 , reference temperature T_0 , and reference elevation Z_0 , and is arbitrarily given the value zero.

Matric potential is the energy per unit volume of water required to transfer an infinitesimal quantity of water from a reference pool of soil water at the elevation of the soil to the point of interest in the soil at reference air pressure. It is a pressure potential that arises from the interaction of water with the matrix of solid particles in which it is embedded. For unsaturated conditions, matric potential has negative values because water added to soil is subject to the attractive forces of capillary and surface absorption that vary with water content. These forces exert negative pressure which draws water from the tensiometer, creating a vacuum within the instrument. The magnitude of this vacuum, measured with a pressure transducer, is proportional to the matric potential.



FIELD USE OF TENSIOMETERS

DRAFT

EG&G ROCKY FLATS PLANT
EMAD MANUAL SOP

Manual:
Procedure No.
Page:
Effective Date:
Organization:

5-21200-OPS
GT.27

6 of 21/17 *Ass*

June 20, 1992

Category 2

Environmental Management

The tensiometers used in this study are manufactured by Soil Measurement Systems, Tuscon, AZ. They consist of a water column tube with a porous ceramic cup base and a septum stopper at the top (Fig. 1). Tension (negative pressure) in the air pocket above the water column is linearly related to the water height in the column and water tension in the soil. Tension is measured and recorded with a Tensicorder¹ for each tensiometer. The actual water tension in the soil around the porous cup is the value on the read-out (mbar*1.02) minus the length (in cm) of the water column in the tensiometer.

For pure water systems (no osmotic effects) the air pressure measured in the water column of the tensiometer (Fig. 1) is equivalent to the matric potential in the soil surrounding the porous cup at the base of the tensiometer (Warrick, 1990). Tensiometers of five different lengths, 16, 28, 40, 52, and 64 inches are used for this study. Optimally, they are arranged in five clusters of five tensiometers along each trench, for a total of twenty-five per trench (Fig. 2). Each cluster is approximately opposite to a hydraulic conductivity measuring site with respect to the trench (see SOP GT.26, Determining Hydraulic Conductivity Using a Tension Infiltrrometer). The tensiometry data and the hydraulic conductivity values provide complimentary data for the solution of the Darcy flux equation. Each of the five tensiometers per cluster measure matric potential from a different horizon or depth. For example, in trench 1 tensiometers monitor matric potential in the A, AB, Bt, Btk, and Btgk horizons at depths of 10, 20, 35, 50, and 70 centimeters, respectively (Fig. 2).

¹Tensicorder is a registered trademark of Soil Measurement Systems.

FIELD USE OF TENSIOMETERS

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EG&G ROCKY FLATS PLANT
EMAD MANUAL SOP

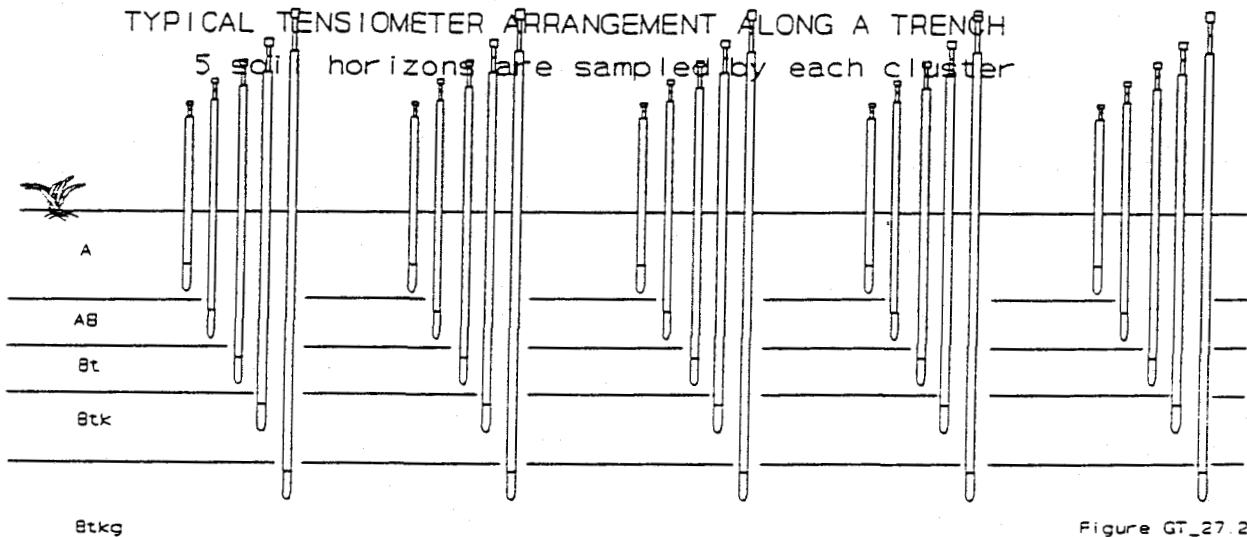
Manual:
Procedure No.
Page:
Effective Date:
Organization:

5-21200-OPS
GT.27
7 of 21 *17*

June 20, 1992

Category 2

Environmental Management



6.0 FIELD USE OF TENSIOMETERS

6.1 MATERIALS AND EQUIPMENT

Below is a checklist for field measurements using tension infiltrometers. Several items are included as a matter of convenience rather than necessity (indicated by *).

Basic Equipment

Tensiometers

Extra septum stoppers

Metric ruler, 15cm

7/8" PVC caps

Tensicorder

Extra batteries for Tensicorder (9 volt)

PPE (as Necessary)

FIELD USE OF TENSIOMETERS

DRAFT

EG&G ROCKY FLATS PLANT
EMAD MANUAL SOP

Manual:
Procedure No.
Page:
Effective Date:
Organization:

5-21200-OPS
GT.27
8 of 21/1

June 20, 1992

Category 2

Environmental Management

18' Aluminum scaffold and supporting blocks

Writing Supplies

Weatherproof field notebook

Black waterproof pens

Soft metal labelling tags

Water Supplies

1-quart nalgene bottles (for refilling tensiometers)

Decontamination supplies (as necessary)

Site Preparation

Augers, for example:

screw type auger: good for wet clayey soil

15/16" OD auger

3/4" tube: good for rocky soil

2" coring auger with 1' shank: for loose, dry soil

Hammer

5-gallon buckets (one for each soil horizon)

10 gallons water for slurry

Tape measure for measuring hole depth

Rod for pushing soil down hole around tensiometer

3 or 4 small, 1-gallon or less buckets or tubs for collecting auger
tailings and transporting slurry

6.2 PROCEDURES

6.2.1 SITE PREPARATION

- Cordon off area behind trench where the tensiometers will be placed. Foliage must be protected from trampelling. All work performed in this area must be done from a scaffold. This scaffold runs parallel to the trench face, supported at least 6" above the ground by blocks at each end. Remove the

FIELD USE OF TENSIOMETERS

DRAFT

EG&G ROCKY FLATS PLANT
EMAD MANUAL SOP

Manual:
Procedure No.
Page:
Effective Date:
Organization:

5-21200-OPS

GT.27

9 of 21

June 20, 1992

Category 2

Environmental Management

scaffold from the area when not in use to minimize trauma to the flora.

- The zone containing the tensiometers must be at least 60cm from the trench face. At this distance the tensiometers will not interfere with other instruments placed in the adjacent face of the trench.

6.2.2 Installation

- Make an access hole using a 15/16 inch OD auger. Drill the hole to a depth approximately 3cm below the desired soil depth.
- Remove soil from auger bit, sort by soil horizon, and place in appropriate slurry buckets.
- Make a slurry (mud) from the soil removed from the hole by mixing enough water to allow it to be poured down the hole. Remove coarse particles (>1cm) from the slurry. Where different soil horizons have been penetrated, separate slurries must be made from the soil of each horizon. When large numbers of tensiometers must be installed, buckets of slurry should be prepared for each horizon which will be encountered. Where applicable, soil from the adjacent trench may be used. Advance preparation of slurries speeds work because certain horizons (e.g. AB and Bt) take time to disassociate into slurry.
- Pour slurry of bottom-hole composition down the hole. Insert the tensiometer into the hole, pushing down firmly enough to seat the ceramic cup into the slurry. Do not push so hard that the fragile ceramic cup is damaged.

FIELD USE OF TENSIOLOGICALS

DRAFT

EG&G ROCKY FLATS PLANT
EMAD MANUAL SOP

Manual:
Procedure No.
Page:
Effective Date:
Organization:

5-21200-OPS
GT.27

10 of 21/17

June 20, 1992

Category 2

Environmental Management

- Pour or push slurries down the hole in sequence to reestablish the soil column. It may be necessary to wiggle the tensiometer to assist downward flow and to eliminate air pockets.
- Fill the tensiometer with water to 1 cm. below the top.
- Place the septum stopper on the tensiometer.
- Label tensiometers.
- Measure the length of the tensiometer above the ground surface. Invert the outer sleeve of the septum stopper to expose the upper edge of the tensiometer for an accurate measurement. Record this information in the field notebook (SOP FO.14).
- Place PVC caps on tensiometers. The septum stoppers must be protected from sunlight by caps.

6.2.3 Maintenance

- The tensiometer must be periodically refilled with water. The frequency of refilling depends on the dryness of the soil surrounding the ceramic cup. When the soil water tension reaches values of 0.5 mbar or higher, frequent servicing is necessary. Once the rate of water column drop is established refilling can be performed often enough that the water level does not drop below the clear, upper portion of the tensiometer. Refilling should be performed immediately after tension measurement to provide maximum time for reequilibration prior to the next measurement.

FIELD USE OF TENSIOMETERS

DRAFT

EG&G ROCKY FLATS PLANT
EMAD MANUAL SOP

Manual:
Procedure No.
Page:
Effective Date:
Organization:

5-21200-OPS
GT.27

11 of 21/17

June 20, 1992

Category 2

Environmental Management

- To refill, remove the stopper and add water up to 1 cm. below the top. More water may have be added to those tensiometers which consistently drain below the viewing area between measurements. An air space of between 1 and 2 cm² air below the septum stopper is optimal for proper pressure readings by the pressure transducer. This air space prevents water from entering the transducer needle.
- Visually inspect the septum stopper for signs of deterioration. Replace with a new stopper if necessary. Replace the stopper and PVC cap.

6.2.4 Automatic Data Collection Using a Tensicorder

A Tensicorder is a portable data storage device (data logger). The SMS Version 3.0 model has memory organized into six pages of five-hundred cells each (total storage of three-thousand readings). Operation of the Tensicorder is via the touchpad interface on the front of the device. Most of the available functions are printed on the touchpad for user convenience. A simple on-line liquid crystal display on the front of the device provides the user with desired information as requested by the appropriate touchpad sequences. Consult the Tensicorder User Manual for additional information. The following steps will be used to program the Tensicorder to record tensiometer data:

- Turn on the Tensicorder.
- Press F 4 1. This selects the transducer as the input device.
- Press F 0. This zeros the offset.
- Press F 6 <page number>. This selects the page number that the data will be stored. Pages available are numbered 0 thru

FIELD USE OF TENSIOLOGS

DRAFT

EG&G ROCKY FLATS PLANT
EMAD MANUAL SOP

Manual:
Procedure No.
Page:
Effective Date:
Organization:

5-21200-OPS

GT.27

12 of 21

June 20, 1992

Environmental Management

Category 2

5. (e.g., F 6 5)

- Press F 5. This allows you to view the current auto input parameters.
- To accept the current parameters:
 - Press YES.
- To change the current parameters:
 - Press NO.
 - At the "SET PARAMETERS [Y/N] ?" query, Press YES.
 - At the "START-NR:" query, enter the number of the storage location you want sampling to start at. Registers available are from 001 to 500 for each page of data.
 - Press 1.
 - Press STO. This stores the starting location.
 - At the "END-NR:" query, again enter 1 to take a single measurement from each tensiometer.
 - Press 1.
 - Press STO. This stores the end location.
 - At the "TIMEBASE:" query, press STO. The increment is irrelevant because measurement is instantaneous.
 - For the example parameters selected, the Tensicorder will automatically record and store, on Page 5, 1 data point for each tensiometer measured.
 - At the "START [Y/N]" query, press YES to start the sampling. Pressing NO puts the unit into the ready mode. To save battery power, the Tensicorder may now be turned off without losing the sampling parameters.

FIELD USE OF TENSIOMETERS

DRAFT

EG&G ROCKY FLATS PLANT
EMAD MANUAL SOP

Manual:
Procedure No.
Page:
Effective Date:
Organization:

5-21200-OPS
GT.27
13 of 217

June 20, 1992

Category 2

Environmental Management

- Place the transducer down onto the top of the tensiometer so that the needle penetrates the septum. The tension will appear in the rightmost column on the display. Press STO to save the measurement. Advance the tensicorder to the next data location by pressing YES (up arrow). Proceed to the next tensiometer, place the transducer, and take the next reading. Repeat for all tensiometers.
- Turn off the tensicorder when finished.

6.2.5 Field Data Collection

- Take measurements from the tensiometers in a prearranged order corresponding to the order of data desired in the spreadsheet (e.g. shallowest to deepest, left to right). Establish a system of I.D. codes for each tensiometer to identify each data point.
- As described above, the tensimeters are arrayed along the margins of five trenches. At each trench they are grouped into five clusters containing five tensimeters of various lengths each (Fig. 2). The corresponding tensimeter I.D.s nomenclature is as follows:

nnTSct

where *nn* is the trench number (01..05), *TS* stands for tensimeter, *c* is the cluster number (1..5 from left to right facing the instrumented trench face), and *t* is the tensimeter number within the cluster (1..5, shortest to longest).

- Follow procedure 6.2.3 for collecting tension data with the tensicorder.
- Measure the water level height in the tensiometer. The best method to measure water height is to first slide up the outer sleeve of

FIELD USE OF TENSIOMETERS

DRAFT

EG&G ROCKY FLATS PLANT
EMAD MANUAL SOP

Manual:
Procedure No.
Page:
Effective Date:
Organization:

5-21200-OPS
GT.27
14 of 21
June 20, 1992
Environmental Management

Category 2

the septum, exposing the upper rim of the tensiometer, and then measure down from the rim to the water surface. Water column height is equal to the length of the tensiometer minus the distance from the top to the water surface. Record this information in the field notebook. In the lab, enter this data as a single column into a Lotus 1-2-3 worksheet. Print the data to a file (*.dat) using a standardized nomenclature (e.g. 6_23mwl.dat = measured water levels recorded on June 23rd).

NOTES

- The Tensicorder reads pressure in millibars (mbar). For spreadsheet calculations use 1 mbar = 1.02 cm of water head.

6.2.6 Data Transfer

6.2.6.1 Data Transfer From the Tensicorder

The Tensicorder is capable of transferring the data which is stored in its memory directly to the serial port of a printer or to the serial port of a computer. Procedures for data transfer are described under SOP GT.26 sec. 6.2.4, Determining Hydraulic Conductivity Using a Tension Infiltrometer.

6.2.6.2 Data Entry From the Field Scientific Notebook

- Water level (measured from the top down) is recorded manually in the field scientific notebook. This data must be properly arranged in a data file (*.DAT) before it may be used in a spreadsheet. To create a data file first enter Lotus 1-2-3. Enter the data in a columnar sequence the same as that used during tensicorder data acquisition. Place a header on each column indicating the data acquisition date.

FIELD USE OF TENSIOMETERS

~~DRAFT~~

EG&G ROCKY FLATS PLANT
EMAD MANUAL SOP

Manual:
Procedure No.
Page:
Effective Date:
Organization:

5-21200-OPS
GT.27
15 of 21
June 20, 1992
Environmental Management

Category 2

6.2.7 Data Analysis

- Enter Lotus 1-2-3. Retrieve the worksheet named TENSII1.WK1. This is the worksheet that has been designed to automatically calculate Z and total head (H). The worksheet should be located in the C:\123\TENSIM directory.
- This spreadsheet contains constants including identification numbers, cup depths and tensiometer lengths. Tensiometer and water level data, arranged in the same order as the constants, may be imported into the spreadsheet. Export calculated values (Z, H) and other pertinent data (e.g. cup depth) to another spreadsheet for further analysis, graphing, etc.

NOTES

- A suggested standard filename nomenclature is as follows:
 - OUTPUT FILE: {path}:TSjul.WK1 jul = Julian date, TS = tensiometer data

7.0 DECONTAMINATION

Specific decontamination procedures are described in SOP FO.3, General Equipment Decontamination, and FO.04, Heavy Equipment Decontamination. Procedures for the handling of personal protective equipment and for decontamination water will follow SOP FO.06, Handling of Personal Protective Equipment and SOP FO.07, Handling of Decontamination Water and Wash Water, respectively.

FIELD USE OF TENSIOMETERS

DRAFT

G&G ROCKY FLATS PLANT
EMAD MANUAL SOP

Manual:
Procedure No.
Page:
Effective Date:
Organization:

5-21200-OPS

GT.27

16 of 21

June 20, 1992

Category 2

Environmental Management

8.0 DOCUMENTATION

The collection and documentation of field hydraulic conductivity will follow guidelines in SOP FO.1.14, Field Data Management. A field notebook will be used for documentation of labeling, manual recording of exposed tensiometer lengths, water level heights, instances of refilling and septum replacement for each sampling location, and other pertinent information.

Note the following information for each test location:

- Date
- Weather
- Technicians name and company affiliation
- Tensiometer I.D. number
- Location (e.g., Rocky Flats Plant, 901 Lip Area, Trench No. 1)
- Tensicorder Data Storage Locations (e.g.: Page 1, download file name = julTDn.DAT).
- A sample data collection form is provided on the following page.

DRAFT

17.8.17

TENSIO METER DATA: WATER LEVELS				903 PAD LIP AREA TRENCHES			
NAME/COMPANY:				DATE:			
WEATHER/NOTES:							
01TS11		02TS22		03TS26		04TS24	
01TS12		02TS23		03TS27		04TS25	
01TS13		02TS24		03TS31		04TS31	
01TS14		02TS25		03TS32		04TS32	
01TS15		02TS31		03TS33		04TS33	
01TS21		03TS32		03TS34		04TS34	
01TS22		02TS33		03TS35		04TS35	
01TS23		02TS34		03TS36		04TS41	
01TS24		02TS35		03TS37		04TS42	
01TS25		02TS41		03TS41		04TS43	
01TS31		02TS42		03TS42		04TS44	
01TS32		02TS43		03TS43		04TS45	
01TS33		02TS44		03TS44		04TS51	
01TS34		02TS45		03TS45		04TS52	
01TS35		02TS51		03TS46		04TS53	
01TS41		02TS52		03TS47		04TS54	
01TS42		02TS53		03TS51		04TS55	
01TS43		02TS54		03TS52		05TS11	
01TS44		02TS55		03TS53		05TS12	
01TS45		03TS11		03TS54		05TS13	
01TS51		03TS12		03TS55		05TS21	
01TS52		03TS13		03TS56		05TS22	
01TS53		03TS14		03TS57		05TS23	
01TS54		03TS15		04TS11		05TS31	
01TS55		03TS16		04TS12		05TS32	
02TS11		03TS17		04TS13		05TS33	
02TS12		03TS21		04TS14			
02TS13		03TS22		04TS15			
02TS14		03TS23		04TS21			
02TS15		03TS24		04TS22			
02TS21		03TS25		04TS23			

Appendix VIII

Tension Infiltrrometer SOP

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

5-21200-OPS
GT.26, Rev. 1
1 of 30
June 15, 1992
Environmental Management

Category 2

DRAFT

TITLE:
DETERMINING HYDRAULIC
CONDUCTIVITY USING
A TENSION INFILTRMETER

Approved By:

(Name of Approver)

(Date)

1.0	TABLE OF CONTENTS	
1.0	TABLE OF CONTENTS	1
2.0	PURPOSE AND SCOPE	3
3.0	RESPONSIBILITIES AND QUALIFICATIONS	3
4.0	REFERENCES	3
	4.1 SOURCE REFERENCES	3
	4.2 INTERNAL REFERENCES	4
5.0	TENSION INFILTRMETER	5
	5.1 DESIGN FEATURES AND PRINCIPLES OF OPERATION	5
	5.2 PROCEDURES	7
	5.2.1 Filling the Infiltrrometer	7
	5.2.2 Calibration	9
	5.2.3 Refilling the Infiltrrometer	12
6.0	FIELD USE OF THE TENSION INFILTRMETER	13
	6.1 MATERIALS AND EQUIPMENT	13
	6.2 PROCEDURES	15
	6.2.1 Preparing the Soil Surface	15
	6.2.2 Conducting Infiltration Measurements	16

Draft

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT	Manual:	5-21200-OPS
EMAD MANUAL OPERATION SOP	Procedure No.:	GT.26, Rev. 1
	Page:	2 of 30
	Effective Date:	June 15, 1992
Category 2	Organization:	Environmental Management

6.2.3	Automatic Data Collection using a Tensicorder ...	17
6.2.4	Data Transfer from the Tensicorder	20
6.2.4.1	Downloading to a Laser Printer	20
6.2.4.2	Downloading to a PC file	22
6.2.4.3	Importing Tensicorder Data into a Lotus 1-2-3 Spreadsheet	24
6.2.5	Estimating Measurement Times	25
6.2.6	Calculations	26
6.2.6.1	Steady-State Infiltration Rate	26
6.2.6.2	Unsaturated Hydraulic Conductivity	28
7.0	DECONTAMINATION	29
8.0	DOCUMENTATION	30

LIST OF FIGURES

FIGURE GT.26.1, Tension Infiltrrometer	6
FIGURE GT.26.2, Calibration Diagram	10

LIST OF FORMS

FORM GT.26.1, Infiltrrometer Data Collection Sheet

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

G&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
3 of 30
June 15, 1992
Environmental Management

Category 2

2.0 PURPOSE AND SCOPE

This standard operating procedure (SOP) describes procedures that will be used at the Rocky Flats Plant (RFP) to determine the hydraulic conductivity of soils using a Soil Measurement Systems (SMS) tension infiltrometer.

Hydraulic conductivity testing will be performed at three soil horizons exposed during trenching operations prior to the installation of interstitial water sampling equipment as described in SOP GT.20, Procedure for Soil Interstitial Water Sampling and Sampler Installation. All activities will be conducted in accordance with the Health And Safety Plan (HSP) that will be developed for these activities.

3.0 RESPONSIBILITIES AND QUALIFICATIONS

Personnel performing hydraulic conductivity testing will be soil scientists, hydrologists, geologists, geotechnical engineers, or technicians with the appropriate amount of applicable field experience or on-the-job training under the supervision of a qualified person.

4.0 REFERENCES

4.1 SOURCE REFERENCES

The following is a list of references reviewed prior to the writing of this procedure:

Soil Measurement Systems; Tension Infiltrometer Users Manual, 1991.

Soil Measurement Systems; Tension Infiltrometer Users Manual, 1992.

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTROMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
4 of 30
June 15, 1992
Environmental Management

Category 2

Soil Measurement Systems; Tensicorder Users Manual, 1992.

M.D. Ankeny, T.C. Kaspar, and R. Horton. 1988. "Design for an Automated Tension Infiltrometer"; Soil Science Society of Am. Journal. Vol 52. pp. 893-896.

M.D. Ankeny, T.C. Kaspar, and R. Horton. 1990. "Characterization of Tillage and Traffic Effects on Unconfined Infiltration Measurements"; Soil Science Society of Am. Journal. Vol. 54. pp. 837-840.

M.D. Ankeny, M. Ahmed, T.C. Kaspar and R. Horton. 1991. "Simple Field Method for Determining Unsaturated Hydraulic Conductivity"; Soil Science Society of Am. Journal. Vol. 55. pp. 467-470.

Gardner, W.R. 1958. "Some Steady-State Solutions of Unsaturated Moisture Flow Equations with Application to Evaporation From a Water Table"; Soil Science. Vol. 85. pp. 228-232.

W.D. Reynolds and D.E. Elrick. 1991. "Determination of Hydraulic Conductivity Using a Tension Infiltrometer"; Soil Science Society of Am. Journal. Vol. 55. pp. 633-639.

W.A. Jury, W.R. Gardner, and W.H. Gardner. 1991. "Soil Physics", Fifth Edition. John Wiley and Sons, Inc. NY pp. 328.

Wooding, R.A. 1968. "Steady Infiltration from a Shallow Circular Pond"; Water Resource. pp. 1259-1273.

4.2

INTERNAL REFERENCES

Related SOPs cross-referenced by this SOP are:

- SOP FO.03, General Equipment Decontamination.

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
5 of 30
June 15, 1992
Environmental Management

Category 2

- SOP FO.06, Handling of Personal Protective Equipment.
- SOP FO.07, Handling of Decontamination Water and Wash Water.
- SOP FO.14, Field Data Management.
- SOP GT.20, Procedures for Soil Interstitial Water Sampling and Sampler Installation.

5.0 TENSION INFILTRMETER

5.1 DESIGN FEATURES AND PRINCIPLES OF OPERATION

Applications of the tension infiltrometer include measurement of macropore and preferential flow, estimation of soil structure, and characterization of the soil hydraulic conductivity/water potential relationship. Figure GT.26.1 shows a schematic diagram of a tension infiltrometer. The scope of work discussed in this SOP will be in conducting studies to determine unconfined, unsaturated, hydraulic conductivity.

The major components of the tension infiltrometer are 1) the bubbling tube, the shorter 2.54 cm (1 inch) ID tube, which controls the tension at the soil surface, 2) the water reservoir or Mariotte column which empties as water flows into the soil, and 3) the baseplate with porous membrane to establish hydraulic conductivity with soil or other porous medium. The polycarbonate frame strengthens the infiltrometer and should be used when carrying the device. Tension (negative pressure) in the air pocket at the top of the water reservoir is linearly related to the height of water in the column. A centimeter change in water column height means a centimeter change in tension in the air pocket. Thus, infiltration rates can be monitored by recording tension changes measured by a Tensimeter or Tensicorder¹ over time. ¹Tensimeter or Tensicorder are registered trademarks of Soil Measurement Systems, Tucson, Arizona.

Tension at the soil surface is controlled by the air entry ports in

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

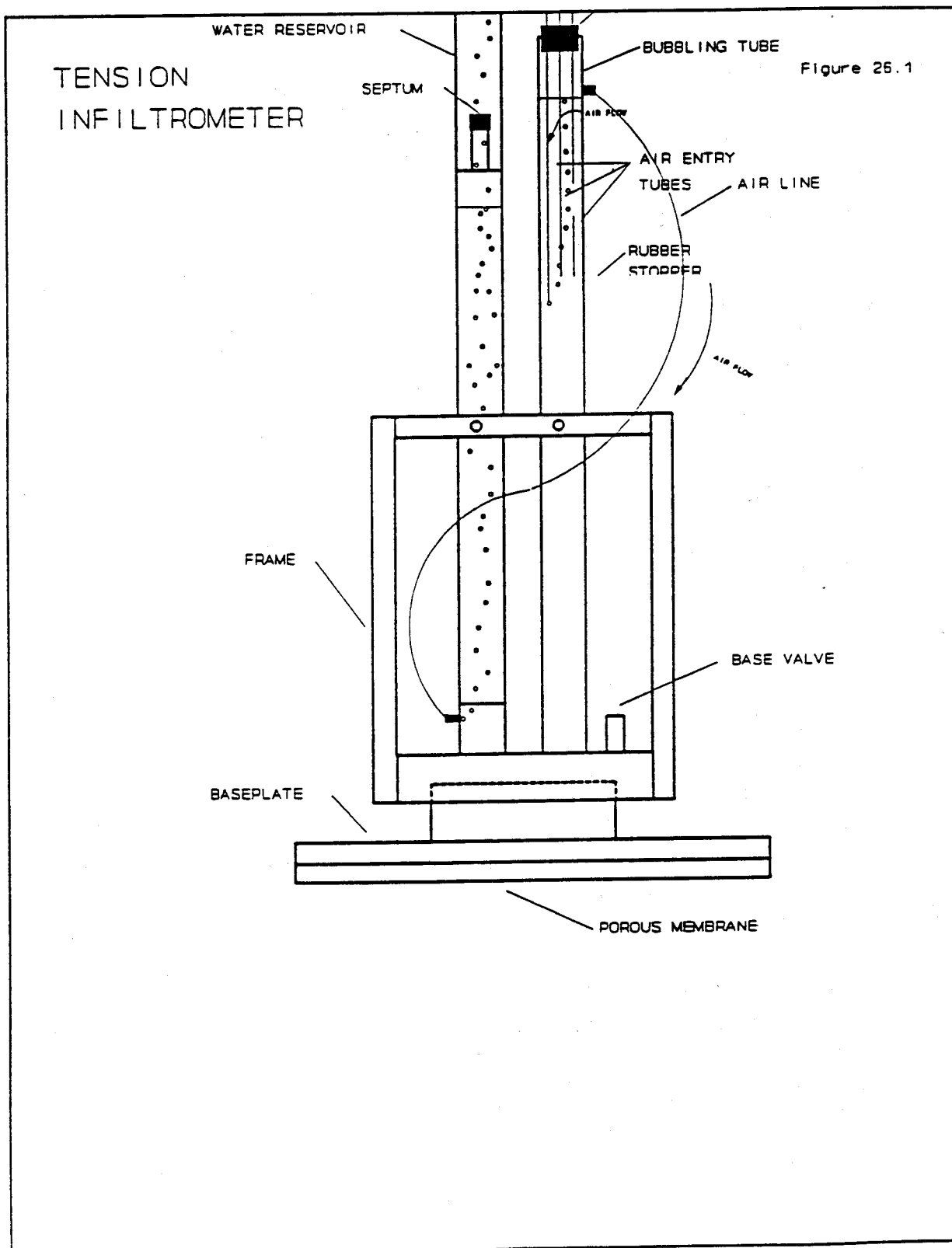
EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
6 of 30
June 15, 1992
Environmental Management

Category 2



DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
7 of 30
June 15, 1992
Environmental Management

Category 2

the bubbling tube. Each of the three air entry tubes can be calibrated to set four different tensions at the soil surface. Tension settings of 0-, 3-, 6-, and 15 cm have proven convenient across a variety of soils and soils conditions (SMS Infiltrrometer Manual). Changing to an air entry tube that ends 3 cm under the water surface from a tube that ends 9 cm under the water surface would decrease water tension at the soil surface by 6 cm.

5.2 PROCEDURES

5.2.1 Filling the Infiltrrometer

- To fill the infiltrrometer for the first time, the baseplate must be submerged in water in order to saturate the pores of the porous nylon mesh attached to the baseplate.
- Place the infiltrrometer into a bucket, dishpan or sink containing enough water to cover the top of the baseplate. Allow the porous nylon mesh to saturate for approximately 15 minutes.
- Along the bubbling tube and water reservoir tube is a metric scale. Fill the bubbling tube with water to about the 3 cm mark.
- Apply silicon oil to the air entry tubes at the rubber stopper and insert the rubber stopper into the top of the bubbling tube. The oil allows ease in moving the plastic air entry tubes in the rubber stopper during calibration and also decreases air entry.
- Initially position the tubes at the 3-, 6-, and 15 cm mark of the bubbling tube scale. Leave the pinch clamp on the 15 cm air entry tube port open.

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

~~DRAFT~~

5-21200-OPS
GT.26, Rev. 1
8 of 30
June 15, 1992
Environmental Management

Category 2

- Attach about 1 meter (3.3 feet) of tygon tubing to a variable speed vacuum pump (i.e., peristaltic). A hand-operated vacuum pump can also be used but would require an additional person to operate it during calibration. Install a 2.54 cm (1 inch) long, 20 gauge hypodermic needle into the tygon tubing and secure with a small hose clamp.
- Insert the needle through the septum stopper located at the top of the water reservoir and, using the vacuum pump, create a vacuum (tension) enough to begin filling of the baseplate. While water enters the baseplate through the porous nylon mesh gently bump the baseplate onto the bottom of the dishpan until all of the air bubbles are forced out of the porous base. Residual air filled pores may result in air leaks through the porous mesh later. A small amount of air bubbles may remain under the baseplate but attempts should be made to keep them to a minimum.
- Increase the vacuum and fill the water reservoir to the 70 cm level. When the water reservoir has filled reduce the vacuum so that the water level remains constant.
- Remove the infiltrometer from the dishpan and gently place onto a countertop or similar level surface covered with plastic (to keep the base clean and countertop dry). Air will begin entering through the open 15 cm air entry port and into the water reservoir (see Figure GT.26.2).
- Visually inspect the porous nylon mesh for water or air leaks and vary the vacuum to maintain a constant stream of air bubbles through the water reservoir. The porous mesh will allow air entry if an open air entry port is set greater than 20-25 cm or if the mesh is not attached properly to the base.

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
9 of 30
June 15, 1992
Environmental Management

Category 2

- Close the 15 cm air entry port and sequentially open the two other air entry ports to purge them of water. Allow each entry port to bubble for approximately 15 seconds. The water level in the bubbling tube should, at this point, be below the zero level on the scale.
- Remove the needle from the septum and shut off the vacuum pump. If the unit is free of air leaks the water reservoir will remain at a constant level and no air bubbles will be seen. The unit is now ready for calibration.

5.2.2 Calibration

The tension infiltrometer shall be initially calibrated in the laboratory prior to use. If infiltrometer studies are to be conducted in the field, it will be necessary to recalibrate the unit at each location, prior to use. The following steps will be performed to calibrate the tension infiltrometer:

- A water manometer will be used to calibrate the applied soil surface tensions. A water manometer is simply water-filled tygon tubing connected to the valve at the base of the infiltrometer and looped over a benchtop, truck tailgate, sample cooler, etc., adjacent to a meter stick (Figure GT.26.1).
- Attach the manometer to the side of the bench such that the zero end of the meter stick is level with the benchtop surface. The benchtop is the zero reference which represents the soil surface.

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

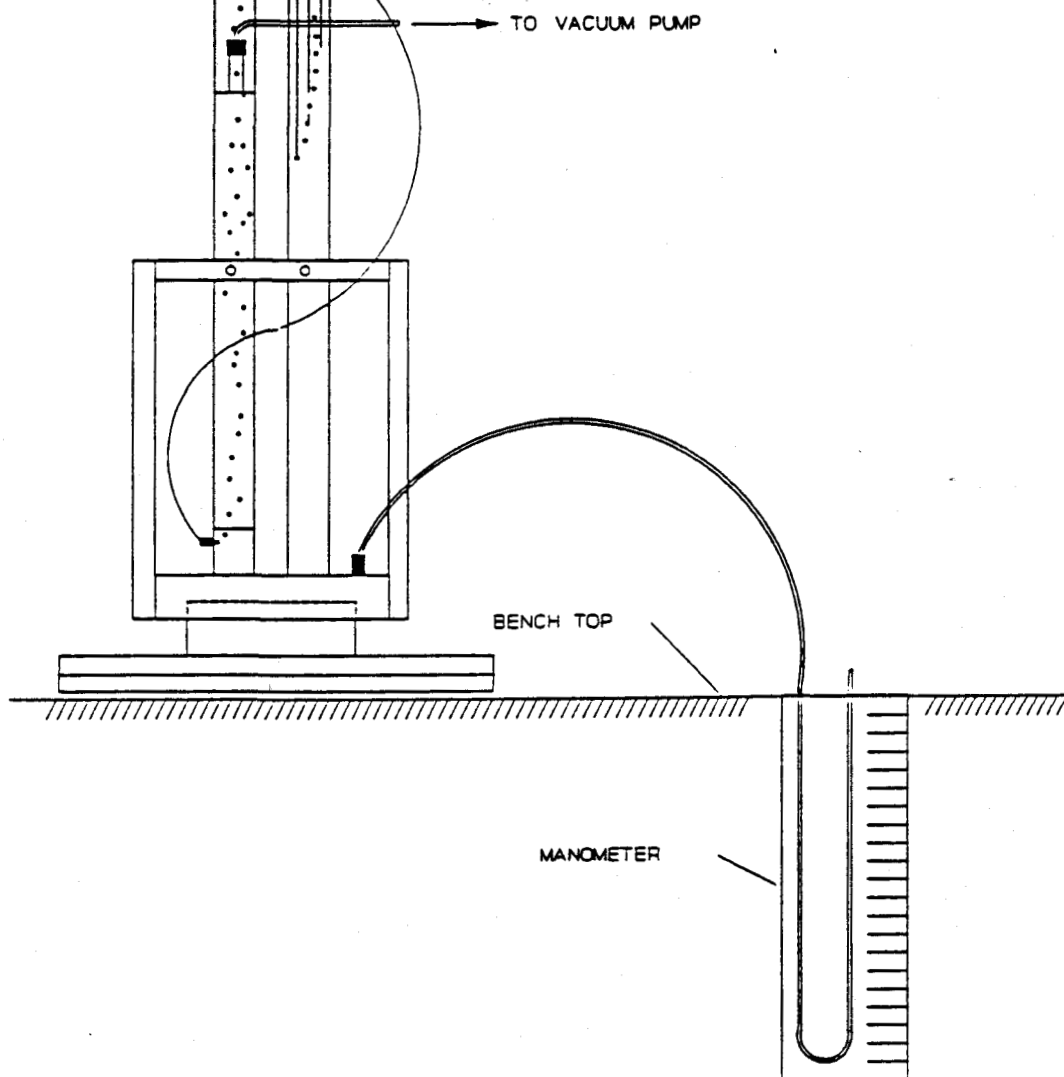
5-21200-OPS
GT.26, Rev. 1
10 of 30
June 15, 1992

Category 2

Environmental Management

TENSION
INFILTRMETER

Figure 26.2



DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTROMETER

B&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
11 of 30
June 15, 1992
Environmental Management

Category 2

- Attach the manometer tubing to the top portion of the base valve.
- Filling the manometer tubing with water is accomplished by connecting the end of the tubing containing the top portion of the base valve to the bottom portion in the base, connecting the open end of the manometer to a vacuum pump, then create a vacuum so that water flows from the water reservoir out of the manometer. Eliminate all air in the tubing and any entrapped in the base.
- Calibration of surface tensions shall be performed from low (3 cm) to high (15 cm) tension. The zero (0) surface tension is then set by moving the 3 cm air entry tube.
- If a 3 cm surface tension is desired, open the clamp of the 3 cm air entry tube, create a vacuum at the top of the water reservoir until a slow, constant stream of bubbles appears in the water reservoir and adjust the air entry tube such that the water level in the manometer reaches the 3 cm level (distance from the benchtop to the top of the water in the tube of the manometer with the water reservoir bubbling).
- Close the 3 cm air entry tube and sequentially calibrate the remaining air entry tubes.
- After all 3 air entry tubes are initially calibrated fill the bubbling tube with water to the zero level. This is accomplished by creating a vacuum at the top of the water reservoir, purging the 6- and 15 cm air entry tubes of water and then squirting water into the open 3 cm air entry port until the water level reaches the zero mark on the bubbling tube scale.

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
12 of 30
June 15, 1992
Environmental Management

Category 2

- Perform a final calibration at all three tension levels in the same sequence as before. Mark the final positions of the lower ends of the air entry tubes on the bubbling tube with a black, waterproof marker. This way any change in the bubbling tube water level or in air entry tube height can be noted and corrected to maintain calibrated tensions.
- A zero surface tension is set by moving the 3 cm air entry tube to a location such that the manometer water level is set at zero.
- Disconnect the manometer from the base valve and refill the water reservoir following procedures explained in Section 5.2.3, Refilling the Infiltrrometer.

Air flowing through the bubbling tube causes water to evaporate, lowering the water level in the tube. Water can be squirted into an open air entry tube (as explained above) to return the water level to the zero mark on the bubbling tube scale.

While surface tensions can be calibrated to an accuracy of millimeters, the precision of tension control is limited by tension fluctuations due to bubbling (+/- approximately 1 cm). Therefore, at very low tension settings, actual soil surface tension may fluctuate to zero potential.

5.2.3 Refilling the Infiltrrometer

- Place the infiltrrometer into a 5-gallon bucket containing several gallons of clean water.
- Open the pinch clamp on the 15 cm air entry port.
- Connect the vacuum pump to the water reservoir septum.

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTROMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
13 of 30
June 15, 1992
Environmental Management

Category 2

- While creating a vacuum in the water reservoir, fill the water reservoir to the desired height. If using a Tensicorder for automatic data collection, the height of the water reservoir column can exceed the 70 cm scale. If data collection is conducted using a timer and noting the water reservoir level, fill the reservoir to the 70 cm level.
- The infiltrometer may remain in the bucket until needed, however, do not allow the unit to be stored over long periods of time in water as bacterial growth on the nylon mesh will reduce the effective soil-to-membrane contact area.
- Be careful not to bump the infiltrometer base allowing air to enter through the porous mesh.

6.0 FIELD USE OF THE TENSION INFILTROMETER

6.1 MATERIALS AND EQUIPMENT

Below is a checklist for field measurements using tension infiltrometers. Several items are included as a matter of convenience rather than necessity (indicated by *). Personal Protective Equipment (PPE) will be specified by the site Health and Safety Plan.

Basic Equipment

Tension Infiltrrometer

Tensicorder

Infiltrrometer Outer Ring

Extra batteries for Tensicorder (9 volt)

Manometer

PPE (as Necessary)

Writing Supplies

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
14 of 30
June 15, 1992

Category 2

Environmental Management

Field notebook
Plot/site maps
Data collection sheets
Black waterproof pens
Clipboard

Water Supplies

5-gal water (depending on number of tests conducted)
1-5 gal bucket (several extra buckets are useful)
2-Plastic dishpans
1-gal plastic jug
Peristaltic pump w/tubing
Hand vacuum pump w/tubing*
Septum needles
12 volt battery (fully charged)
Decontamination supplies (as necessary)

Site Preparation

Pointed trowel
Flat-nose shovel
Cheese cloth
Silica sand for contact material
Straightedge
Scissors*

Miscellaneous Supplies

Paper towels
Threaded support rods ('legs' for Infiltrrometer)
Garbage bags
Timer/stopwatch
Calculator
Rubber mallet
Folding table
Vacuum grease/silicon oil

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTROMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
15 of 30
June 15, 1992
Environmental Management

Category 2

Measuring tape
Second Infiltrometer/Ring*
Spare septa*
Spare wiring*
Adjustable wrench*
Screwdriver*
Pliers*
Allen Wrench*
Hose clamps
Flags to Mark Site*

6.2 PROCEDURES

6.2.1 Preparing the Soil Surface

Infiltration can be measured with or without removal of any soil crust although plant roots, worm holes, rocks, and fractures in the soil will affect infiltration rates and hydraulic conductivity data. The following steps will be performed to correctly prepare the soil surface:

- Using a pointed trowel, remove 10-15 cm of soil surface in a 25-30 cm diameter and level the area. If the soil is too wet to avoid smearing, the measurement should wait. Avoid areas containing large rocks and plant roots.
- Press the outer ring into the prepared surface such that the ring is flush with the surface.
- If large cracks appear in the soil surface, place 3 layers of cheesecloth on the soil surface inside the ring.
- Place slightly moistened contact material (e.g., fine, white, silica sand similar to that used in ashtrays) in the ring and

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTROMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
16 of 30
June 15, 1992

Category 2

Environmental Management

level with a straight edge. The cheese cloth reduces sand slaking into soil macropores.

- Place the infiltrometer (water reservoir should be full) onto the center of the sand and gently press the device down onto the sand. Note that the effective diameter for calculating the hydraulic conductivity is the diameter of the sand circle that comes into contact with the porous mesh, $r = 4.2$ cm (1.65 inches) or 12 cm (4.72 inches).
- Inspect the sand/mesh interface to assure good contact. Poor contact results in poor data. A "target" type of leveling indicator is convenient to assure that the infiltrometer is perpendicular to the soil surface.
- The infiltrometer is anchored by securing the four sharpened, threaded rods at the corners of the base. Air will leak in through the porous mesh if there is insufficient pressure placed onto the sand by the infiltrometer.

6.2.2 Conducting Infiltration Measurements

Without moving the infiltrometer, tests to determine hydraulic conductivity are conducted for at least two surface tension settings (e.g., low: $h_1 = 0$ cm and high: $h_2 = -3$ cm). For this project and soil types expected to be encountered, testing will be performed at four surface tension settings, 0-, 3-, 6-, and 15 cm, at each location. Although at low surface tensions (i.e., 0, 3 cm) a relatively large amount of water is added to the soil water front, the soil remains in an unsaturated state. Testing will be performed at increasing surface tensions (e.g., $h_1 = 0$). Data collection can be performed either manually, using a stopwatch and noting the height of the water reservoir, or automatically, using

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTROMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
17 of 30
June 15, 1992
Environmental Management

Category 2

a Tensicorder or data logger.

- To manually obtain data, the change in water level in the water reservoir during infiltration can be read directly on the attached cm scale. A simple timer or stopwatch is useful to obtain readings at regular time intervals.
- The change in water level can also be obtained automatically by placing the transducer head of a Tensicorder over the septum stopper on the upper end of the water reservoir. The tension read on the digital read-out of the Tensicorder is directly proportional to the water level in the water reservoir (Note: 1 mbar = 1.02 cm of water head). Thus, a 5 cm drop in the water reservoir level causes a 5 cm drop in tension (5.1 mbar).

6.2.3 Automatic Data Collection using a Tensicorder

A Tensicorder is a portable data storage device (data logger). The SMS Version 3.0 model has memory organized into six pages of five-hundred cells each (total storage of three-thousand readings). Operation of the Tensicorder is via the touchpad interface on the front of the device. Most of the available functions are printed on the touchpad for user convenience. A simple on-line liquid crystal display on the front of the device provides the user with desired information as requested by the appropriate touchpad sequences. Consult the Tensicorder User Manual for additional information. The following steps will be used to program the Tensicorder to automatically record infiltrometer data:

- Turn on the Tensicorder.
- Press F 4 1. This selects the transducer as the input device.

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
18 of 30
June 15, 1992

Category 2

Environmental Management

- Press F 0. This zeros the offset.
- Press F 6 <page number>. This selects the page number that the data will be stored. Pages available are numbered 0 thru 5. (e.g., 0)
- Press F 5. This allows you to view the current auto input parameters.
- To accept the current parameters:
 - Press YES.
- To change the current parameters:
 - Press NO.
 - At the "SET PARAMETERS [Y/N] ?" query, Press YES.
 - At the "START-NR:" query, enter the number of the storage location you want sampling to start at. Registers available are from 001 to 500 for each page of data.
 - Press <start number>. (e.g., 001)
 - Press STO. This stores the starting location.
 - At the "END-NR:" query, enter the number of the storage location you want sampling data to end at.
 - Press <end number>. (e.g., 250)
 - Press STO. This stores the end location.
 - At the "TIMEBASE:" query, use the up/down arrow keys to select the desired time increment. Time increments available are 0.4-, 2-, 4-, 10-, and 20 seconds and 1-, 2-, 5-, and 10 minutes. When the preferred increment is displayed store the value.
 - Press YES (up) or NO (down).

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
19 of 30
June 15, 1992
Environmental Management

Category 2

- Press STO. (e.g., 4 seconds)
- For the example parameters selected, the Tensicorder will automatically record and store, on Page 0, 250 data points at 4-second discrete intervals for a total time interval of 1000 seconds.
- At the "START [Y/N]" query, press YES to start the sampling. Pressing NO puts the unit into the ready mode for realtime reading. To save battery power, the Tensicorder may now be turned off without losing the sampling parameters.

NOTES

- Any key pressed during auto-sampling will stop the process.
- If auto sampling must be stopped midrun then simply record the last used storage location and redefine the automatic collection parameters so that they start at the next storage location.
- The Tensicorder reads pressures in millibars (mbar). For the "change in water column height" calculations, 1 mbar = 1.02 cm of water head.
- At the conclusion of testing at each surface tension setting, reset the Tensicorder to record the next testing storage locations and time intervals. High surface tension settings (i.e., $h_s = -15$ cm) require longer sampling time intervals. The following discrete sampling intervals for surface tension settings have been used in the laboratory and should be considered and used during data collection in the field:

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
20 of 30
June 15, 1992

Category 2

Environmental Management

Tension Setting (cm)	Discrete Interval (secs)	Total Interval (secs)	No. of Readings
0	1.0	250	250
3	4.0	1000	250
6	4.0	1000	250
15	10.0	2500	250

- For consistent data collection for all sampling locations, tests between surface tension settings should begin not less than 5 minutes and no later than 10 minutes after the conclusion of the previous test.
- At the conclusion of the test at the fourth and final surface tension place the infiltrometer into a 5-gallon bucket containing several gallons of water and, carefully, remove the silica sand from the mesh. Transfer the infiltrometer to another bucket containing clean water and allow the unit to remain there while moving to the next location. The bucket provides a stable means of transporting the infiltrometer while keeping the porous nylon mesh saturated.

6.2.4 Data Transfer From the Tensicorder

The Tensicorder is capable of transferring the data which is stored in its memory directly to the serial port of a printer or to the serial port of a computer.

6.2.4.1 Downloading to a Laser Printer.

Before attempting the data transfer the correct connections must be made between the printer and the Tensicorder. A RS-232 cable is required going from 9 pin to 25 with the number 2 pin crossing with the number 3 pin and the number seven going pin to pin. The cable

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
21 of 30
June 15, 1992

Category 2

Environmental Management

is plugged into the Tensicorder at the 9 pin end and into the first serial port of the printer with the 25 pin end. The procedure for doing the actual transfer is as follows:

- Turn on the printer.
- Press ON LINE to toggle the printer off-line.
- Press and hold the MENU button until SYM SET appears.
- Press MENU to scroll through the parameter topics. Stop at the I/O=PARALLEL topic.
- Press - to switch the option to I/O=SERIAL.
- Press ENTER to save the new parameters.
- Press MENU to see the current BAUD RATE.
- Press + or - to select the BAUD RATE = 4800.
- Press ENTER to save the new baud rate.
- Press MENU until the READY screen is displayed.
- Press ON LINE.
- Turn on the Tensicorder.
- Press F 6 to select the page that you want to print.
- Press F 7 8 and enter the number of columns that you want data printed out in, (1 to 4).
- Press F 2 to go through the data transfer parameters.

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
22 of 30
June 15, 1992
Environmental Management

Category 2

- Press YES in response to the NO PARITY query.
- Press YES in response to the 2 STOPBIT query.
- Press YES or NO to scroll through the choices of baud rates.
- Press STO when 4800 BAUD is displayed.
- Press F 1 to send the data to the printer.

6.2.4.2 Downloading to a PC file

This procedure is used to transfer stored data from the Tensicorder to the CPU of an IBM compatible computer. The cable connection between the Tensicorder and the PC is the same as explained in Section 6.2.4.1, Downloading to a Printer.

- The communication parameters on the PC must agree with the settings on the Tensicorder. At the DOS prompt type:

MODE COMn: baud, parity, databits, stopbits

where:

n	Serial Port number (e.g., 1).
baud	Baud rate (e.g., 48 for 4800).
parity	Parity (e.g., n for no).
databits	Use 8.
stopbits	Number of stopbits (e.g., 2).

For example if the Tensicorder has been set as described and the Tensicorder is attached to COM1, the proper command is:

MODE COM1: 48,n,8,2 <RETURN>

The computer responds with the communications settings and returns

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
23 of 30
June 15, 1992
Environmental Management

Category 2

to the DOS prompt.

- Copy the contents of the Communications Buffer into a File.
- At the DOS prompt type:

`COPY COMn:[path]filespec`

where: (example for Trench X-1, Location 1)

n Serial Port number (e.g., 1)
path Optional Path for output file. The [] are not
typed. (e.g., C:\INFIL\
filespec Output file name (e.g., X1_01.DAT)

For example if the Tensicorder is attached to COM1 and the desired output file name is X1_01.DAT in the C:\INFIL directory in DOS the proper command is:

`COPY COM1:C:\INFIL\X1_01.DAT <RETURN>`

The computer does not return to the DOS prompt but writes all the data received in the COM1 buffer to the output file.

- Send the data from the Tensicorder to the computer.
- On the Tensicorder Press F 1. F 1 will appear in the left hand side of the Tensicorder display and stay there until data transmission is finished.
- Send an EOF (end-of-file) from the Tensicorder to the computer.
- At the end of data transmission Press F 7 7. The computer will respond by indicating that one file has been copied

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

Draft

5-21200-OPS
GT.26, Rev. 1
24 of 30
June 15, 1992
Environmental Management

Category 2

and return to the DOS prompt. The data has been saved to the specified output file.

6.2.4.3 Importing Tensicorder Data into a Lotus 1-2-3 Spreadsheet

This procedure is used to download stored data from the Tensicorder into a Lotus 1-2-3 spreadsheet.

- Download the stored data within the Tensicorder, to a C:*.DAT file. Follow the procedure outlined in subsection 6.2.4.2; Downloading to a PC file. The data file (*.DAT) will contain only numbers. (e.g., X1_01.DAT)
- Boot up Lotus 1-2-3.
- Once in Lotus, go to the Import subdirectory. To get to the subdirectory type:

\F (File) ---> \I (Import) ---> \N (Numbers)

This will transfer the numbers from the data file (*.DAT) to a worksheet file (*.WK1) so the worksheet functions can be utilized.

- Once the computer returns to the 'Ready' mode, do any necessary edits to make the data presentable. Some examples are moving the data to desired cell locations or deleting rows or columns that are not needed etc.
- Save this file under any name you choose. (e.g., X1_01.WK1)
- Keep track of the file names and their contents in the Scientific Notebook according to the Scientific Notebook Plan.
- Erase the worksheet from the screen after you have saved the

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTROMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
25 of 30
June 15, 1992
Environmental Management

Category 2

data. This is done by typing:

\W (Worksheet) ---> \E (Erase)

- Retrieve the worksheet named X1_01.WK1. This is the worksheet that has been designed to automatically calculate the Ksat, Q_1 , Q_2 , etc. Follow the previously mentioned procedure to retrieve this worksheet.
- Once this file comes up on the screen and the computer is in the 'Ready' mode, the data from the Tensicorder (stored in the previous worksheet) is added. This is done by typing:

/F (File)--> /C (Combine)--> /A (Add)--> /E (Entire File)

- Add the file where the Tensicorder data was stored (e.g., X1_01.WK1). Add this data directly under the headings.
- Once the data from the Tensicorder appears on the screen, make any necessary edits. One edit may be to break up the data that was added. Each page on the Tensicorder has 500 storage locations, but since we usually use 250 storage locations for each surface tension on the Infiltrometer, the data will need to be broken up into two-250 line columns.
- The final step is to save this file (after all the pages on the Tensicorder have been added), so the data can be manipulated later.

6.2.5 Estimating Measurement Times

To determine the hydraulic conductivity of soil it is necessary to reach steady-state infiltration at, at least, two surface tensions. The time needed to obtain a steady-state rate in unsaturated infiltration measurements depends upon initial soil water content,

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTROMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
26 of 30
June 15, 1992

Category 2

Environmental Management

soil compaction, tillage, and hydraulic properties of the given soil. In general, drier soils, highly compacted soils, and soils of lower hydraulic conductivity result in a longer time interval needed to reach a steady-state infiltration rate. Also, each increase in applied surface tension causes a decrease in the infiltration rate, with the largest decrease occurring between 0 and 3 cm tension (Ankeny et al, 1990). Increasing surface tension decreases the infiltration rate because this increase reduces the size and number of pores in the soil conducting water. The change in the infiltration rate over time should be monitored to confirm that steady-state rates are reached. Data is collected for 1000 seconds under most conditions except dry, high bulk density areas where a larger data collection interval may become necessary. Not reaching steady-state results in an overestimate of hydraulic conductivity. In very porous and sandy soils, steady-state rates are reached much earlier and measurement times can be shorter. As a rule of thumb, if one third of the water reservoir tube has emptied, enough water has been added to the soil water front to approach steady-state. This may aid in deciding when to terminate one measurement and start another. The downloading of Tensicorder data to a graphing software file (Lotus 1-2-3, PCGraph etc.) visually helps to determine an asymptotic steady-state infiltration relationship. Avoid spilling water onto the test area when refilling the water reservoir between tension settings becomes necessary. This additional moisture will affect the hydraulic conductivity.

6.2.6 Calculations

6.2.6.1 Steady-State Infiltration Rate

With the tension infiltrometer one measures the volume of water per unit time, Q ($\text{cm}^3 \text{ hr}^{-1}$), entering the soil column through the porous nylon mesh at two applied surface tensions, e.g., h_1 and h_2 .

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTROMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

Draft

5-21200-OPS
GT.26, Rev. 1
27 of 30
June 15, 1992
Environmental Management

Category 2

where:

$$Q(h_n) = \pi r^2 K_{sat} \exp(\alpha h_n) \left[1 + 4 / (\pi r \alpha) \right] \quad \text{for } n = 1, 2, 3, \text{ and } 4 \quad (1)$$

where K_{sat} (cm/hr) is the field saturated hydraulic conductivity, α (cm^{-1}) is the soil texture/structure parameter that measures the relative importance of gravity and capillarity forces during water movement in unsaturated soil (Reynolds, 1991), and r is the radius of the sand layer between the mesh and the soil ($r = 4.2$ or 12 cm).

The value of Q is obtained by first calculating the steady-state flux q (cm/hr) at each surface tension.

- For each surface tension select a time interval where the drop in water level in the water reservoir remains constant over time.

Example (Wooding, 1968):

If upon reaching steady-state flux, the water level in the supply tube (ID = 2.54 cm) fell on average 20 cm/hr for $h_1 = -5$ cm, and 10 cm/hr when the tension was set to give $h_2 = -15$ cm.

Then steady-state infiltration rates (Q) are calculated using:

$$Q = A \text{ (surface area of column)} \times q \text{ (flux)}$$

$$Q_1 = \pi (d/2)^2 (20) = (3.14) (2.54/2)^2 (20) = 101.3 \text{ cm}^3/\text{hr}$$

$$Q_2 = \pi (d/2)^2 (10) = (3.14) (2.54/2)^2 (10) = 50.7 \text{ cm}^3/\text{hr}$$

Note that the higher the tension setting (less negative) the greater the infiltration rate.

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

E&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
28 of 30
June 15, 1992
Environmental Management

Category 2

Using the equation: $\alpha = \frac{\ln[Q(h_2)/Q(h_1)]}{h_2 - h_1}$ (2)

Because $Q(h_1)$ and $Q(h_2)$ are measured and h_1 and h_2 are known, α can be computed.

With α known calculate K_{sat} from equation (1).

$$\alpha = \frac{\ln(50.7/101.3)}{-15 - (-5)} = 0.0692 \text{ cm}^{-1}$$

From (1) one obtains:

$$101.3 = (3.14)(4.2)^2 K_{sat} \exp[0.0692(-5)] [1 + 4/(3.14)(4.2)(0.0692)]$$

$$K_{sat} = 0.35 \text{ cm/hr}$$

With α and K_{sat} known and using Gardner's Equation (1958):

$$K(h) = K_{sat} \exp(\alpha h) \quad \text{for } h \leq 0. \quad (3)$$

where $K(h)$ is the hydraulic conductivity-pressure head relationship (cm/hr).

From (3) one can calculate the unsaturated hydraulic conductivity, as follows:

$$\begin{aligned} h = -10 \text{ cm}, & \quad K(-10) = 0.17 \text{ cm/hour} \\ h = -20 \text{ cm}, & \quad K(-20) = 0.07 \text{ cm/hour} \\ h = -100 \text{ cm}, & \quad K(-100) = 0.00035 \text{ cm/hour} \end{aligned}$$

The values of α and K_{sat} may vary with applied surface tension settings.

When data is collected for four surface tensions, h_1 , h_2 , h_3 , and h_4 , corresponding to applied surface tensions of 0-, 3-, 6-, and 15 cm,

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTROMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
29 of 30
June 15, 1992
Environmental Management

Category 2

respectively, calculate α and K_{sat} for all adjacent values of applied surface tensions (i.e, h_1 and h_2 , h_2 and h_3 , etc). Average the resulting values for $\alpha = \alpha_{ave}$ and $K_{sat} = K_{sat}$ (Equation 4).

$$\alpha_{ave} = [\alpha(0,3) + \alpha(3,6) + \alpha(6,15)]/3 \quad (4)$$

$$K_{sat} = [K_{sat}(0,3) + K_{sat}(3,6) + K_{sat}(6,15)]/3$$

Substitute these into Gardner's Equation (Equation 3) for each surface tension to calculate the unsaturated hydraulic conductivity at that tension (Equation 5).

$$K(h) = K_{sat} \exp(\alpha_{ave} h) \quad \text{for } h \leq 0 \quad (5)$$

However, rather than taking four surface tension settings at each location, you could use just two tension settings, determined through experimentation with the soil type, but double the number of measurement locations. This way you get a better idea of the spatial variability in K_{sat} at α .

7.0 DECONTAMINATION

Specific decontamination procedures are described in SOP FO.3, General Equipment Decontamination, and FO.04, Heavy Equipment Decontamination. Procedures for the handling of personal protective equipment and for decontamination water will follow SOP FO.06, Handling of Personal Protective Equipment and SOP FO.07, Handling of Decontamination Water and Wash Water, respectively.

8.0 DOCUMENTATION

DETERMINING HYDRAULIC CONDUCTIVITY USING A TENSION INFILTRMETER

EG&G ROCKY FLATS PLANT
EMAD MANUAL OPERATION SOP

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

DRAFT

5-21200-OPS
GT.26, Rev. 1
30 of 30
June 15, 1992
Environmental Management

Category 2

The collection and documentation of field hydraulic conductivity will follow guidelines in SOP FO.1.14, Field Data Management. Form GT 26.1, Infiltrometer Data Collection Sheet will be used in the field for the recording of tension infiltrometer settings and Tensicorder readings for each sampling location.

Note the following information for each test location:

- Date
- Time
- Weather
- Technicians name and company affiliation
- Infiltrometer number (No. 1 or 2)
- Location (e.g., Rocky Flats Plant, Trench No. X-1, Horizon A, depth = 10 cm. below grade, Test No. 1)
- A diagram of test locations within the trench.
- Tensicorder Data Storage Locations (e.g., $h_2 = -3$ cm; Page 0, Start: NR=251, End: NR=500, discrete time interval = 4 seconds, duration of test = 1000 seconds, download file name = X1_01.DAT and X1_01.WK1).

INFLTRMETER DATA COLLECTION SHEET

Project No.: 4006-167

Checked By: _____

Computed By:

Infiltrrometer No.: _____

Infiltrrometer No.:

Date:

Technician:

[illegible]

Total Time Interval: $\Delta T = \Delta(NK - NK_0)$

CALCULATIONS TO DETERMINE UNSATURATED HYDRAULIC CONDUCTIVITY

[illegible]

$h = 3 \text{ cm}$

SURFACE TENSION: Ψ_n (cm); example: for $x_n = 0.5$ cm, $\Psi_n = 0.5$ cm.

MATRIX POTENTIAL; μ (cm)

MATRIX POTENTIAL; μ (cm)

ESTIMATED HYDRAULIC CONDUCTIVITY; K_{SAT} (cm/hr)

STEADY-STATE INFILTRATION FLUX: $q_n = (\Delta l / \Delta t)_n$ = the steady-state change in water content, cm/hr.

$$= \left(\frac{\text{mm Hg/sec}}{\text{cm}^2} \right) \times (\text{area of water reservoir tube}).$$
$$Q(h_n) = (\pi r^2) \times q_n = \frac{\pi r^2}{\alpha} \frac{dh_n}{dt}$$

STEADY-STATE INFILTRATION VOLUMETRIC

$$Q(h_r) = \pi r^2 X K_{SAT} X \exp(\alpha h_r) [1 + 4/\pi \alpha]$$
$$\frac{h_2 - h_1}{h_1}$$

where $r = 4.2$ or 12 cm (radius of porous membrane).

$$K(h_n) = K_{\text{SAT}} \exp(\alpha h_n).$$

Gardner's Equation

DRAFT

Appendix IX

Piezometer Information

OCT 07 1992

WCC/DENVER



GEO ENVIRONMENTAL EASI GROUNDWATER SAMPLING SYSTEM

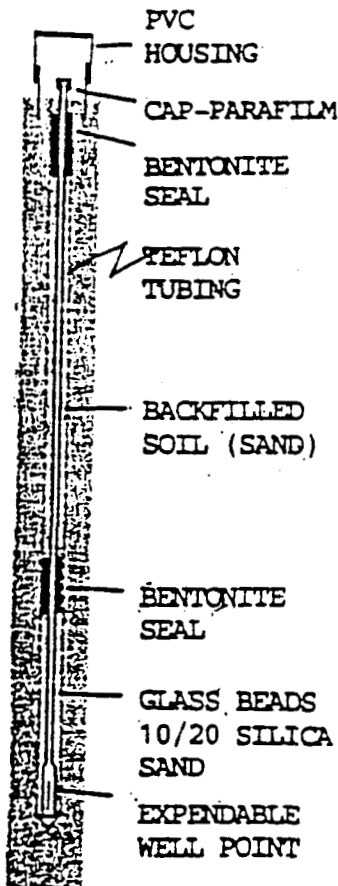
=====

Expendable Aquifer Sampling Implants (EASI)

GEO Environmental uses the EASI system to sample groundwater for real-time or temporary monitoring. The expendable well point is driven into the ground to the desired sampling depth. The probe rods are retracted exposing 6" of perforated 3/8" teflon tubing. If purgeable groundwater is present, a sample is collected using one of two sample pumps. If no purgeable water is present, the EASI system is completed like a conventional monitor well (see illustration). The system is allowed to sit for 3 to 5 days to establish a static groundwater level. The groundwater sample is collected using one of two pumping systems.

EASI CAPABILITY

-
- Groundwater sampling to 30'.
 - Measure groundwater levels to 0.1".
 - Well materials cost less than \$20.00.
 - One man crew, easy to install.
 - Truly expendable temporary, can stay in place for days or months.
 - No soil cuttings generated.
 - Designed to pinpoint permanent monitor well locations, thus saving costs of possible unnecessary wells.
 - Ideal for clay lithologies where purgeable groundwater is hard to obtain.



SOP Number: SAM-2 REV 0

Date: March 4, 1992

Approved by: E. S. S. S.
Director of Chemistry

GROUND WATER SAMPLING PROCEDURES

Introduction:

This method contains procedures which are suitable for the collection of groundwater samples before installing expensive and sometimes unnecessary monitoring wells. This technique does not comply with EPA protocol for valid groundwater sampling, but can be used as a screen or qualitative indicator of groundwater quality.

Summary:

Groundwater samples can be collected by two different means. If purgeable water is present, a groundwater sample can be collected immediately. If no water is present, Easy Aquifer Sampling Implants (EASI) can be installed and completed similar to the installation of monitor wells. After 3-5 days, groundwater samples are collected using either an vacuum pump or peristaltic pump.

Apparatus and Materials:

All Terrain Vehicle Scorpion (ATV) with Stanley sinker drill attached to the rear of vehicle that is hydraulically driven from a PTO.

-OR-

Pickup mounted Giddings GSR drill rig uses auguring capabilities to get to depth.

-OR-

Hand-driven AMS (Art's Manufacturing Supplies) probing equipment or hand-driven augers.

Sections of 1" O.D. rod (1/2" I.D) that come in two lengths, three foot and two foot. The hand-held rods are 5/8" O.D. and 1/2" I.D. and come in three foot lengths.

Expendable well points. Stainless-steel drive points that attach to the 1" rods.

3/8" teflon tubing with 6" of 1/16" perforations in the bottom of the tubing.

Parafilm to seal the open end of the tubing from ambient air.

Electric vacuum pump or peristaltic pump for sample collection.

40 mL, 20 mL, liter, and 1 gallon sterile environmental sampling containers with teflon lined lids.

Nitrile gloves for handling the sampler and containers.

Bentonite grout and 10/20 silica sand for completing the EASI implants.

1 to 2" O.D. PVC or steel pipe with cap to create surface casing and seal.

Level D, C, B, or A personal protection equipment as required per site specific safety plan.

Alconox laboratory cleaning powder, tap water for washing, and de-ionized distilled water for rinsing.

Sterile squirt bottles for the distilled water

Steam cleaner with biodegradable soap used for larger decontamination situations (GEO personnel, augers, rods, hand-held augers, rigs)

Procedure:

Before preceding with groundwater sampling, make sure that all equipment has been thoroughly de-conned with alconox solution and that the GEO rig has been de-conned with the steam cleaner.

Utilizing one of GEO Environmental's rigs or hand-held equipment, get situated on top of the sampling location of interest.

Auger down into the ground using 2" augers, making sure the hole is as near to vertical as possible (unless the client has made a special request to deviate from the verticle). Auger down to the top of the soil sampling zone, cleaning the hole out with augers as necessary.

If using the Scorpion rig, hydraulically push and hammer a 1" pilot hole down to the top of the groundwater level.

After a pilot hole, or augured hole has been made, the 1"

probe rods are attached to the expendable well point and driven to the specificized sampling depth. The 3/8" perforated tubing with a specialized fitting is inserted inside of the 1" probe rods and screwed into the expendable well point.

If purgeable groundwater is present, the probe rods are retracted 1 to 2 feet off of the well point, exposing the perforated tubing to the groundwater. One of the two pumps is then attached to the 3/8" tubing at the surface and a groundwater sample is pumped to the surface for collection into one of the various sampling containers.

If purgeable water is not present, the probe rods are completely removed from the borehole. A sand filter pack is poured around the tubing perforations from 1 to 5 feet up in the bottom of the hole. 4 to 5 " of bentonite powder is then poured on top of the sand pack to seal off possible surface filtration. The borehole is then backfilled with natural fill and once again sealed at the surface with bentonite. PVC casing is grouted in at the surface, the 3/8" tubing is sealed with parafilm, and the pvc is capped (see illustration).

The EASI system is allowed to sit for 3 to 5 days until a static water level is established. Groundwater levels are measured using the Little Dipper, then a groundwater sample is collected using one of the two sample pumps.

The groundwater sample is put in a sample jar, sealed, labeled, logged in, and put in a refrigerator or iced cooler at 4 degrees celsius.

The augers, probe rods, sampling equipment is then decontaminated using alkanox or the steam cleaner before the next groundwater sample is collected.

Ourlity Assurance:

The field sampling technician documents all sampling depths, locations, and number of sample containers submitted for analysis. If needed, collection of rinse water can be submitted for analysis to ensure the integrity of the decon procedures.

Appendix X

Rain Simulation Calculations

Table 3. Results of calculations

[illegible]

Appendix XI

SSG_SNBK Bernoulli Data Diskette Index

SSG SNBK Bernoulli data diskette Index

The directory structure of the SSG_SNBK Bernoulli data diskette is shown in figure Append-X-1 below. A file containing this directory structure is included in the root directory of the diskette. It is called *DISKDIR* and is in the ASCII format. A copy of this appendix, *APPEND_X.WP5*, is also included in the root directory (WordPerfect 5.1 format). The following sections contain details on the location and format of the specified data.

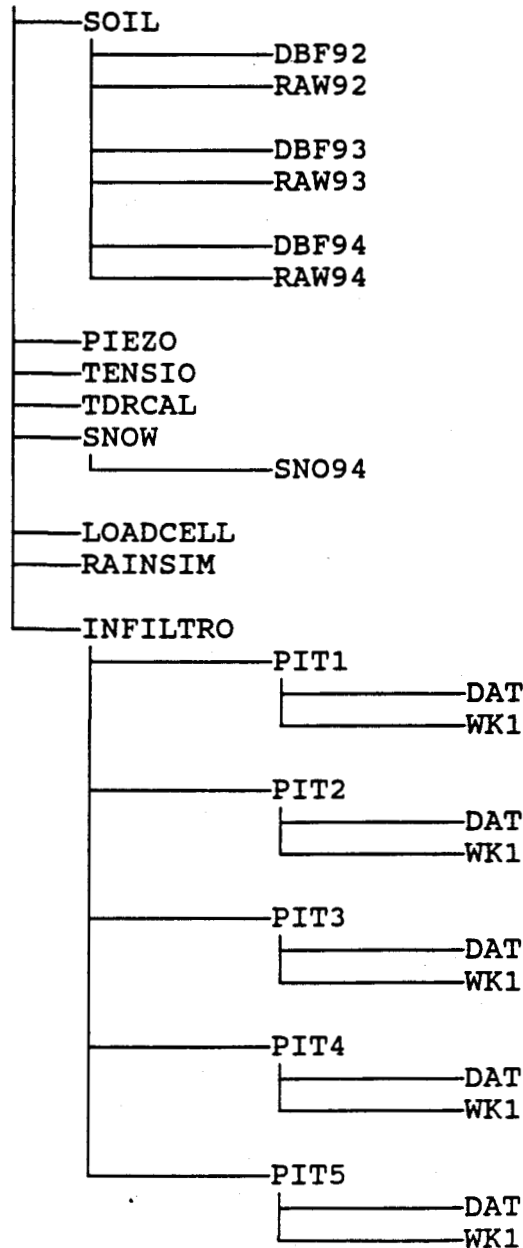


Figure Append-X-1: SSG_SNBK Bernoulli Data Diskette Directory Structure

Load Cell Calibration Data Location

Load cell calibration data is contained in the `\LOADCELL` directory. The file is named `10_5LOAD.XLS` and is in the Excel 4.0 format. Details of the load cell calibrations are included in Appendix VI.

Tension Infiltrometer Data Location

Tension infiltrometer data is contained in the `\INFILTRO` directory. For each of the five pits there is a corresponding subdirectory, such as `\INFILTRO\PIT1`. Each of the pit directories contains two subdirectories, `DAT` and `WK1` (see figure Append-X-1). Raw field data (comma delimited ASCII) is in the `DAT` directories. Lotus 123 versions are in the `WK1` directories. For example, tension infiltrometer raw field data for pit 1 is contained in the `\INFILTRO\PIT1\DAT` directory, while the Lotus 123 versions are in the `\INFILTRO\PIT1\WK1` directory.

Tensiometer Matric Potential Data Location

Tensiometer matric potential field data is in the `\TENSIO` directory. `TNS92.WK3` contains the data for 1992, `TNS93.WK3` for 1993. These files are in the Lotus 123 format, and include a complete description of the data presented.

TDR Calibration Data Location

TDR calibration data is contained in the `\TDRCAL` directory. These files are in the Lotus 123 format. Details of the TDR calibrations are included in Appendix VI.

TDR Soil Moisture Data Location

TDR soil moisture data is archived in two formats: CSI raw data arrays and in a database. Both of these formats are outlined below:

TDR soil moisture raw data:

TDR soil moisture raw data is contained in the \SOIL\RAW9- directories. These files contain the raw field data collected by the CSI TDR component. The files are in the comma delimited ASCII format. All raw data sets are archived with a file name based on the date collected, and the *.raw extension. For example, a data set collected on March 2, 1994 would be archived as 030294.raw. Each file contains a large TDR data array and a smaller rain gauge array (if a rain event occurred), identified with different array number IDs (see the 'Rain Gauge Data Location' section below). The format of these raw data arrays was standardized in August 1993. This standardization included the TDR array number ID of 444. The WordPerfect 5.1 file TDR_RAW.DIR in the \SOIL directory contains a description of the array formats and array number IDs used prior to August 1993. If TDR soil moisture data (or any of the data included in the TDR data array) is needed, it is advised that it be extracted from the database format (described below). The database format contains headers for easy identification of record fields.

For *.raw files dated August 1993 onward, each file contains a data array (comma delimited) with the following format:

data array element(s)	type of data stored																								
1	array number ID																								
2	Julian day																								
3	time																								
4..27	<p>Pit 1 TDR soil moisture contents (%).</p> <p>These 24 values correspond to the 24 TDR probes labelled as instruments 16-39 in Figure 4.1.4-2 'Instrumentation Location Map: Pit 1 NW Face.' For example:</p> <table><tr><td>4:01TDR111</td><td>10:01TDR123</td><td>16:01TDR221</td><td>22:01TDR313</td></tr><tr><td>5:01TDR112</td><td>11:01TDR124</td><td>17:01TDR222</td><td>23:01TDR314</td></tr><tr><td>6:01TDR113</td><td>12:01TDR211</td><td>18:01TDR223</td><td>24:01TDR321</td></tr><tr><td>7:01TDR114</td><td>13:01TDR212</td><td>19:01TDR224</td><td>25:01TDR322</td></tr><tr><td>8:01TDR121</td><td>14:01TDR213</td><td>20:01TDR311</td><td>26:01TDR323</td></tr><tr><td>9:01TDR122</td><td>15:01TDR214</td><td>21:01TDR312</td><td>27:01TDR324</td></tr></table>	4:01TDR111	10:01TDR123	16:01TDR221	22:01TDR313	5:01TDR112	11:01TDR124	17:01TDR222	23:01TDR314	6:01TDR113	12:01TDR211	18:01TDR223	24:01TDR321	7:01TDR114	13:01TDR212	19:01TDR224	25:01TDR322	8:01TDR121	14:01TDR213	20:01TDR311	26:01TDR323	9:01TDR122	15:01TDR214	21:01TDR312	27:01TDR324
4:01TDR111	10:01TDR123	16:01TDR221	22:01TDR313																						
5:01TDR112	11:01TDR124	17:01TDR222	23:01TDR314																						
6:01TDR113	12:01TDR211	18:01TDR223	24:01TDR321																						
7:01TDR114	13:01TDR212	19:01TDR224	25:01TDR322																						
8:01TDR121	14:01TDR213	20:01TDR311	26:01TDR323																						
9:01TDR122	15:01TDR214	21:01TDR312	27:01TDR324																						

28..51	<p>Pit 2 TDR soil moisture contents (%).</p> <p>These 24 values correspond to the 24 TDR probes labelled as instruments 16-39 in Figure 4.1.4-3 'Instrumentation Location Map: Pit 2 NW Face.'</p>
52..75	<p>Pit 3 TDR soil moisture contents (%).</p> <p>These 24 values correspond to the 24 TDR probes labelled as instruments 16-39 in Figure 4.1.4-4 'Instrumentation Location Map: Pit 3 NW Face.'</p>
76..99	<p>Pit 4 TDR soil moisture contents (%).</p> <p>These 24 values correspond to the 24 TDR probes labelled as instruments 16-39 in Figure 4.1.4-5 'Instrumentation Location Map: Pit 4 NW Face.'</p>
100..123	<p>Pit 5 TDR soil moisture contents (%).</p> <p>These 24 values correspond to the 24 TDR probes labelled as instruments 11-34 in Figure 4.1.4-6 'Instrumentation Location Map: Pit 5 NW Face.'</p>
124..126	<p>Pit 1 load cell output (mV/V).</p> <p>These 3 values correspond to the 3 load cells labelled as instruments 58-60 in Figure 4.1.4-2 'Instrumentation Location Map: Pit 1 NW Face.'</p> <p>For example:</p> <p>124: 01LC01 125: 01LC02 126: 01LC03</p>
127..129	<p>Pit 2 load cell output (mV/V).</p> <p>These 3 values correspond to the 3 load cells labelled as instruments 64-66 in Figure 4.1.4-3 'Instrumentation Location Map: Pit 2 NW Face.'</p>
130..132	<p>Pit 3 load cell output (mV/V).</p> <p>These 3 values correspond to the 3 load cells labelled as instruments 62-64 in Figure 4.1.4-4 'Instrumentation Location Map: Pit 3 NW Face.'</p>
133..135	<p>Pit 4 load cell output (mV/V).</p> <p>These 3 values correspond to the 3 load cells labelled as instruments 66-68 in Figure 4.1.4-5 'Instrumentation Location Map: Pit 4 NW Face.'</p>

136..137	<p>Pit 5 load cell output (mV/V).</p> <p>These 2 values correspond to the 2 load cells labelled as instruments 56-57 in Figure 4.1.4-6 'Instrumentation Location Map: Pit 5 NW Face.'</p>
138..140	<p>Pit 1 soil temperatures.</p> <p>These 3 values correspond to the 3 temperature probes labelled as instruments 61-63 in Figure 4.1.4-2 'Instrumentation Location Map: Pit 1 NW Face.' Temperature probe depths are given in Table 4.7.2-1 'Temperature Probes.' For example:</p> <p>138: 01TP01 139: 01TP02 140: 01TP03 depth 13cm depth 27cm depth 66cm</p>
141..146	<p>Pit 2 soil temperatures.</p> <p>These 6 values correspond to the 6 temperature probes labelled as instruments 58-63 in Figure 4.1.4-3 'Instrumentation Location Map: Pit 2 NW Face.' Temperature probe depths are given in Table 4.7.2-1 'Temperature Probes.'</p>
147..150	<p>Pit 3 soil temperatures.</p> <p>These 4 values correspond to the 4 temperature probes labelled as instruments 58-61 in Figure 4.1.4-4 'Instrumentation Location Map: Pit 3 NW Face.' Temperature probe depths are given in Table 4.7.2-1 'Temperature Probes.'</p>
151..158	<p>Pit 4 soil temperatures.</p> <p>These 8 values correspond to the 8 temperature probes labelled as instruments 58-65 in Figure 4.1.4-5 'Instrumentation Location Map: Pit 4 NW Face.' Temperature probe depths are given in Table 4.7.2-1 'Temperature Probes.'</p>
159..161	<p>Pit 5 soil temperatures.</p> <p>These 3 values correspond to the 3 temperature probes labelled as instruments 53-55 in Figure 4.1.4-6 'Instrumentation Location Map: Pit 5 NW Face.' Temperature probe depths are given in Table 4.7.2-1 'Temperature Probes.'</p>
162	CR10 data logger voltage
163	CR10 data logger temperature
164	Year

TDR soil moisture database:

The raw field data files are continually sorted and appended to the *SOILMEAS.DBF* database. The complete database *SOILMEAS.DBF* for 1992 is in the \SOIL\DBF92 directory. The complete database *SOILMEAS.DBF* for 1993 is in the \SOIL\DBF93 directory. The current database *SOILMEAS.DBF* for 1994 (through the end of March) is in the \SOIL\DBF94 directory. These files are in the standard database format (tab delimited ASCII) and can be imported directly into both dBase IV (old RFP standard) and FoxPro (current RFP standard).

All the *SOILMEAS.DBF* files are standardized, and follow the same set-up of the raw format outlined above. All the database files contain headings for the identification of data fields within the database file.

Piezometer Data Location

Piezometer data is contained in the \PIEZO directory. This data is in two formats, comma delimited ASCII and Excel 4.0. The ASCII files have a *.txt extension, the Excel 4.0 files have the *.xls extension. Piezometer data from 1993 are in the *PIEZO93.** files, 1994 data is in the *PIEZO94.** files. The first column is decimal Julian date, columns 2-6 correspond to pits 1-5. This field data corresponds to rain simulations during the summer of 1993, and snowmelt events in early 1994.

Soil Temperature Data Location

The soil temperature data is collected by the TDR component. Please see the 'TDR Soil Moisture Data Location' section for details on the location of soil temperature data.

Rain Gauge Data Location

Rain gauge data is collected with the TDR soil moisture data. The rain gauge raw data is included in the TDR *.raw datafiles (see 'TDR Soil Moisture Data Location' section above). Rain gauge data collected August 1993 onward are identified with the array number ID of 5. See the WordPerfect 5.1 document *TDR_RAW.DIR* (in the *|SOIL* directory) for array number ID's before this data. The rain gauge data array have the following format:

data array element(s)	type of data stored
1	array number ID
2	Julian day
3	time
4	amount of rain (inches)

Rain gauge data in the database format (*.DBF) are included in the *|SOIL\DBF94* subdirectory. The rain gauge database file is named *SNOWMELT.DBF*. This file contains all the rain gauge data collected since 1992. The name was due to the assumption that rainfall would be collected with snow melt values, which are instead collected with the rest of the snow melt data. The rain gauge database file name will be updated to *RAIN.DBF* in the future.

Rain Simulator Calibration Data Location

The rain simulator calibration data is contained in the *|RAINSIM* directory. The file is named *SPRAYER.WK1*, and is in the Lotus 123 format.

Snow Melt Data Location

Snow melt data is contained in the \SNOW\SN094 directory. These files contain the raw field data collected by the CSI Snow Melt component. The files are in the comma delimited ASCII format. All raw data sets are archived with a file name based on the date collected, and the *.sno extension. For example, a data set collected on March 2, 1994 would be archived as 030294.sno.

Each file contains a data array with the following format:

data array element(s)	type of data stored
1	array number ID
2	Julian day
3	time
4..8	snow melt measured by snow melt pans (number of tips by Texas Electronics rain gauge)
9..13	SDS snow depth (mm)*
14..17	RM Young wind direction (invalid values)
18..21	RM Young wind speeds* (18..19 w/ CR10 Pulse channel, valid values) (20..21 w/ SDM-INT8, invalid values)
22..24	MET wind velocities*
25	Eppley Lab pyranometer, incoming short-wave*
26	Eppley Lab pyranometer, reflected short-wave*
27	Eppley Lab pyrgeometer, incoming long-wave*
28	(empty)
29	REBS net radiometer*
30..32	HMP35C relative humidities
33..35	HMP35C atmospheric temperatures
36..45	Pit 1 CSI 107 temperatures: (36..42 - snow temperature profile) (43 - shielded atmospheric temperature) (44..45 - soil temperatures)

46..56	Pit 3 CSI 107 temperatures: (46..52 - snow temperature profile) (53 - shielded atmospheric temperature) (54..55 - soil temperatures) (56 - snow melt pan rain gauge internal temp)
57..65	Pit 5 CSI 107 temperatures: (57..63 - snow temperature profile) (64 - shielded atmospheric temperature) (65 - snow melt pan rain gauge internal temp)
66	CR10 data logger voltage
others:	Data in elements > 66 are used for system refinement and debugging.

* Data collected without conversions before March 10, 1994.
Before this date:

- Solar data was in millivolts, needed conversions:
 Eppley Lab incoming short-wave: $108.1 * \text{mV} = \text{W/m}^2$
 Eppley Lab reflected short-wave: $112.4 * \text{mV} = \text{W/m}^2$
 Eppley Lab incoming long-wave: $270.3 * \text{mV} = \text{W/m}^2$
 REBS net radiometer: $12.9 * \text{mV} = \text{W/m}^2$
- The solar instruments (which are mounted on a 10 m instrument tower) were leveled on March 10. Solar data before this date (especially incoming short-wave) should be used with caution until adjusted.
- Wind velocity data was in rotation counts per minute, needed conversions (based on 1-min interval):
 RM Young: $0.00163 * \text{counts} = \text{m/s}$
 MET: $0.0133 * \text{counts} = \text{m/s}$
- SDS snow depths were collected with different offsets. Each dataset includes bare ground conditions. New snowfall amounts are determined from these 'zero-lines.'